
**COMBAT RATION
ADVANCED MANUFACTURING
TECHNOLOGY DEMONSTRATION
(CRAMTD)**

"Implementation of Integrated Manufacturing"
Short Term Project (STP) #16

FINAL TECHNICAL REPORT
Results and Accomplishments (September 1992 through July 1995)
Report No. CRAMTD STP #16 - FTR23.0
CDRL Sequence A004
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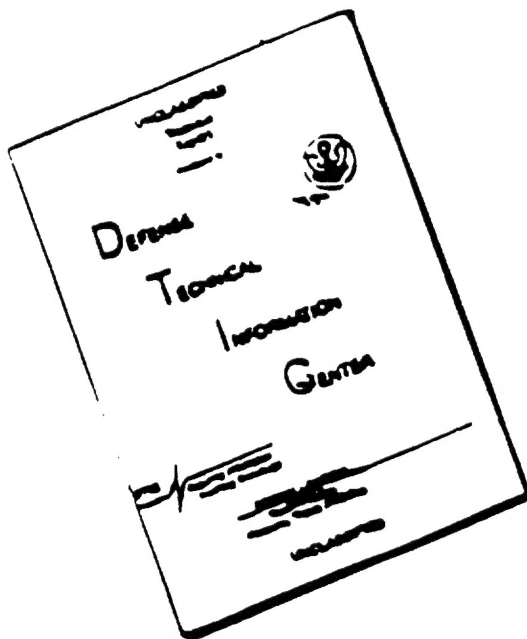
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1.0 CRAMTD STP #16

Results and Accomplishments

This Final Technical Report covers the activities for CRAMTD Short Term Project, STP #16, "Implementation of Integrated Manufacturing".

1.1 Introduction and Background

The objective of this project was to implement integrated manufacturing in the Phase II CRAMTD facility in order to demonstrate the use of advanced technology in the manufacture of combat rations. Preliminary design and development work on components of a computer controlled manufacturing system was performed during Phase I of CRAMTD project under various STP's. Under STP #1, a powered conveyor/seamer subsystem for tray pack packaging was developed. Under STP #8, a horizontal form/fill/seal machine was procured as the packaging subsystem for MRE pouches. These two subsystems were automated at level 1 (machine level) and, in both cases, included some aspects of automation at level 2 (production line level).

Level 2 automation includes incorporating statistical process control. Statistical process control was studied under STP #3 and preliminary recommendations were made concerning parameters to be monitored in the production process. Based on the availability of sensors, the recommendations of STP #3 were to be reviewed and some parameters of the process were to be automatically monitored to demonstrate statistical process control at level 2 automation.

Level 2 automation includes interlocking the control of unit operations along the filling/packaging line. In STP #2, the alternatives for automatic filling were identified and a decision was made to acquire a volumetric filler for solid ingredients. In order to complete level 2 automation, it was deemed necessary to place the packaging and filling equipment under a common production line controller such that all subsystems along the production line could have their operations monitored and coordinated at a central point.

Under STP #4, a preliminary factory database was designed from studying the operations of coalition companies in the packaged food industry. This database was designed to support functions at level 2 (production line), level 3 (factory floor), and level 4 (plant). In order to demonstrate the implementation of integrated manufacturing, it was deemed necessary to link this database with factory floor controllers in order to demonstrate how data can be automatically logged and saved to a factory database.

Under STP #5, a survey and review of available hardware and software was conducted such that Phase II of CRAMTD could begin by selecting off-the-shelf components for computer integration. Recommendations were made to purchase software that would enable linking of the factory floor controllers with the factory database via a SCADA (Supervisory Control and Data Acquisition) node.

STP #16 was defined to review the recommendations of these prior STP's and to propose a specific plan for implementing computer integration for demonstration purposes. STP #16 was proposed on June 23, 1992 and was awarded on September 30, 1992.

1.2 Results and Conclusions

An integrated design for the CRAMTD Pouch Line was successfully developed and implemented. The design brings together the control of the filling, packaging, and crate loading operations under a single controller. The design provides a complete level 2 control system through the implementation of a production line controller ("Centralized Control Station"), which can be implemented as a stand alone module. The design also provides hooks to level 3 and level 4 automation through the implementation of a shop floor SCADA (Supervisory Control and Data Acquisition) node.

The integrated system was successfully demonstrated in part and as a whole at Annual Contract Briefings on November 18, 1993, March 8, 1995 and June 19, 1996, as well as during an industry/academic conference on April 28, 1994. These demonstrations showed that this integrated design is feasible and could be considered by an industrial company for implementation in a commercial plant.

1.3 Recommendations

Operating experience is required with the integrated production lines defined and installed during the "Implementation of Integrated Manufacturing" Short Term Project. Such experience would substantiate the results of the Non-traditional Capital Investment Criteria (NCIC) analysis reported in "Multicriteria Evaluation of a Centralized Control Station for a Production Line: A Case Study", Engineering Valuation and Cost Analysis, 1996, Volume 1, pp 17 - 32 (also CRAMTD FTR 22.0) and verify the designs developed for the production lines.

Integrated manufacturing, including control of a multicomponent processing line and acquisition of the data sufficient for statistical process control, is forecast to increase in priority as advanced packaging and filling equipment is acquired by combat ration producers.

The successor DLA program to CRAMTD, CORANET, includes demonstration production at the Rutgers/CAFT Food Manufacturing Technology Facility (CRAMTD Phase II Demonstration Site). It is recommended that demonstration production seek to maximize utilization of the "Centralized Control Station" with a variety of food products to acquire experience and performance data.

Based on positive experience and performance data, it would then be recommended that a technology transfer program be constituted to assist in implementation of the "Centralized Control Station" at the combat ration producer plants.

2.0 Program Management

This STP was proposed as a two phase activity as illustrated in Figure 1, "Time & Events and Milestones" (Appendix 4.1). The two phases are as follows:

Phase I Prototyping and Establishing System Design Requirements

Phase II Implementation and Technology Transfer

Specific objectives of Phase I are: procure the Shop Floor Control software and factory database system; establish design requirements for integration of SPC and Materials Handling; a Table of plant operating personnel; and an integrated design and control strategy for demonstration production.

During Phase II, design implementation and demonstration included: acquisition of necessary computer hardware and final software; integration and implementation of Shop Floor control and database systems; personnel training; and demonstration production. In addition, a CIM conference focussing on process industries will be organized and held.

2.1 Summary of STP Accomplishments

- A design for the integration of the MRE Pouch Line was developed that includes Level 2 automation as a stand alone system and partial level 3 and level 4 automation.
- The hardware and software components of the control system were successfully built and implemented in the CRAMTD demonstration facility.
- Integration of data acquisition was also accomplished on the Tray Pack line and subsequently modified for use on the Polymeric Tray line.
- These integrations of mechanical systems and information systems were successfully demonstrated at contract briefings.

3.0 Short Term Project Activities

3.1 STP Phase I Task

In this phase, the contractor was responsible for bringing together technical accomplishments of previous related STP's in order to begin prototyping of software for implementation in this STP. In addition, the contractor was responsible for coordinating with new design requirements from STP #14 (Engineered Systems for Handling Material and Product Between Processing Operations) and STP #12 (Sensors for Statistical Process Control). The output of this phase is a final design recommendation.

3.1.1 Prototyping of Shop Floor Control Software (3.4.1)

Based on the recommendation of STP #5, this task item was responsible for procuring factory floor control software and beginning to interface this software with the existing Tray Pack line and MRE pouch line. From the 4th quarter of 1992 through the 2nd quarter of 1993, equipment was being moved from the CRAMTD Phase I pilot plant to the CRAMTD Phase II facility. During this period, work focused on preparing the shop floor and shop floor equipment for integration. A communication module was installed between the Tray Pack line check weigher and the Tray Pack line PLC to be used to transfer data on tray weights to the PLC for collection by the shop floor control software. A computer interface was developed for the Enersyst oven to allow a user to save programs and download program parameters. The use of this software is documented in Technical Working Paper (TWP #73), "Enersyst Oven Programmable Controller Interface Users Manual: Version 1.0" and the software code is documented in Technical Working Paper (TWP #78), "Enersyst Oven Program Technical Manual".

The SCADA node software known as FIXDMACS, a product of Intellution, Inc., was recommended for use in CRAMTD Phase II by STP #5. Approval to order this software was received in September, 1993 and the software was procured in November, 1993. During the 1st and 2nd quarters of 1994, development work proceeded on integrating the Tray Pack line to the SCADA node. Programs were developed for the automatic collection of tray weight data, monitoring tray counts and rejects, monitoring downtime and fault conditions, and monitoring production rates and line efficiencies. Programs developed for the Tray Pack line were designed to be usable, with modifications, on the polymeric line. Documentation of work performed during this period appears in Technical Working Paper (TWP #88), "Level 2 Automation of the Tray Pack Line", Appendix 4.4. This task item was completed in the 3rd quarter of 1993.

3.1.2 Prototyping Factory Database (3.4.2)

Based on the recommendations of STP #4, this task was to begin implementing prototype database software on a multi-user Oracle Database Management System. During the 1st quarter of 1993, a file server and client work stations were borrowed to set up a local area test network to be used as a development platform. In the 2nd quarter, MFG Systems Corp., a coalition partner, was brought in to assist the project team in the use of Oracle CASE, a tool for documenting Oracle database applications so that they can be easily supported through their life cycles. A decision was made to implement all application software through Oracle CASE and several training classes were held by MFG Systems Corp during the 3rd quarter of 1993. During the second half of 1993, work focused on prototyping two modules using Oracle CASE: a materials management module and the quality assurance module. These prototype database modules were demonstrated at the Annual Contract Briefing on November 18, 1993.

During the first half of 1994, work focused on implementing a purchasing module and a stand-alone maintenance module. In addition, Oracle integration with FIXDMACS was accomplished during this period. By the end of the 2nd quarter, prototype operator interface screens had been developed that were capable of sending data to the Oracle database from

FIXDMACS and of receiving data by query to the database.

Documentation of some of the work performed during this period appears in Technical Working Paper (TWP #87), "Quality Assurance for Raw Materials and Finished Goods: Database Design and Implementation", Appendix 4.3. This task was complete in July, 1994.

3.1.3 Incorporate SPC Design Requirements for Demonstration (3.4.3)

This task item addressed software and hardware integration of Statistical Process Control (SPC) requirements to be integrated into the overall demonstration plan. This required coordination with personnel working under STP #12, "Implementing of Sensors and Quality Control Strategies in the Integrated Manufacturing System".

From June, 1993 through May, 1994, coordination meetings were held with the Principal Investigator of STP #12 to integrate SPC requirements into the overall demonstration plan. These meetings culminated in the development of a proposal, "Report on Proposed Integration of MRE Pouch Line for Demonstration Runs", Appendix 4.2, forwarded to the CRAMTD Technical Steering Committee on July 27, 1994. Recommendations included in-line automatic data collection on various machines in the MRE line, as well as on-line quality data collection and off-line quality data collection requiring manual data entry at a terminal. These recommendations were accepted and became part of the demonstration plan. This task item ended in the 2nd quarter of 1993.

3.1.4 Incorporate Materials Handling Control Requirements for Demonstration (3.4.4)

This task item addressed software and hardware integration of new materials handling requirements into the overall demonstration plan. This required coordination with personnel working under STP #14, "Engineered Systems for Handling Materials".

As in the case of task item 3.3.3, above, coordination meetings were held from June, 1993 through May, 1994 with the Principal Investigators of STP #14. These meetings culminated in the development of a proposal, "Report on Proposed Integration of MRE Pouch Line for Demonstration Runs", forwarded to the CRAMTD Technical Steering Committee on July 27, 1994. Recommendations concerning the integration of materials handling included product feeders, the Tiromat and Solbern conveyor systems, the FEMC filler, Oden filler and Adept robot for filling placeables, the Hi-Speed checkweigher and the retort loader and associated infeed conveyor. These recommendations were accepted, but a subsequent review of available funds resulted in deletion of the product feeders, which were not considered essential for the demonstration runs. This task item ended in the 2nd quarter of 1994.

3.1.5 Establish Final Factory Database Design (3.4.5)

The purpose of this task item was to specify which database modules would be implemented in final and how the factory database would be incorporated into the demonstration runs. This task item was executed during the period October, 1993 through May, 1994. During that period the project team coordinated with plant personnel in training them on the use of modules

that were prototyped under task item 3.3.2 and refining these modules in order to finalize their design. Recommendations were forwarded in the proposal "Report on the Proposed Integration of MRE Pouch Line for Demonstration Runs", which was forwarded to the CRAMTD Technical Steering Committee on July 27, 1994, Appendix 4.2. This recommended the implementation of the following modules for the demonstration runs: Materials Control, Raw Material Quality Control, Finished Goods Quality Control, and Work-in-Process Data Collection. These recommendations were accepted and became part of the demonstration plan. This task item ended in the 2nd quarter of 1994.

3.1.6 Develop a Table of Operating Personnel (3.4.6)

This task item required the contractor to develop a preliminary table of functions and associated personnel requirements for operating the demonstration facility. This table was developed and documented in the "Report on Proposed Integration of MRE Pouch Line for Demonstration Runs", dated July 27, 1994.

3.1.7 Tray Pack Lidding Process (3.4.7)

Early experience with Beef Chucks and Gravy in Tray Pack led to consideration of incorporating into the Tray Pack Line a device to press and clinch the tray lid onto the tray bottom.

Preliminary cost estimates from equipment manufacturers were very high and not cost effective. On the other hand, laboratory results showed that large uniform chunk beef size represented a worst-case scenario. The selection of beef chunk size (and size distribution) along with longer beef precooking can eliminate the need for pressing while remaining within specification limits.

3.1.8 Report on Integrated Design

The completion of Phase I was a milestone event in which all of the planning activities were incorporated into a report on the proposed integration and demonstration runs. Two documents were delivered: "Report on Proposed Integration of MRE Pouch Line for Demonstration Runs", Appendix 4.2 and "Specification for Control System for Horizontal Form-Fill-Seal Production Line", ("Centralized Control Station")(included in Appendix 4.2 as attachment E). The latter document specified the hardware and software requirements to implement the integration and was the basis for obtaining contractor bids. A recommendation was made to implement the production line controller and award the contract to Precision Automation, Inc., the low cost bidder, who also scored first on the overall weighted criteria. This recommendation was accepted. Phase I of STP #16 ended in July, 1994.

3.2 STP Phase II Tasks

In this phase the contractor was required to implement the integrated design of Phase I and to execute demonstration runs at the facility.

3.2.1 Acquisition of Hardware and Software (3.5.1)

This task item required the contractor to acquire the hardware and software needed to implement the integrated design proposal of Phase I. The major item to be acquired was the MRE production line control system. The recommendation to subcontract the acquisition of the control system was approved and a contract was signed with Precision Automation and work began during the 4th quarter of 1994. The production line control system included a production line programmable logic controller (PLC), to which the controllers for all unit operations along the line were to be interfaced. This PLC then became the master control station for the line. The production line control system, "Centralized Control Station", also included a control panel that would house an operator panel with all functions to control the line at level 2, an operator panel for programming the Adept robot, an operator panel for programming the Tiromat form/ fill/seal machine, the major piece of equipment on the line, and a view node for the operator to view data being collected by the FIXDMACS shop floor SCADA node. This integrated system was successfully implemented and demonstrated at the Annual Contract Briefing on June 19, 1996.

3.2.2 Software Development and Implementation at Level 2 (3.5.2)

This task item required modifying existing controller software and implementing shop floor programs at the SCADA node. Some of these tasks were conducted in conjunction with Precision Automation as the subcontractor implemented the design under task item 3.2.1.

Under this task item, the shop floor local area network, Allen-Bradley Data Highway Plus, was installed. Both the Tray Pack line and the MRE pouch line were integrated with the FIXDMACS SCADA node over Data Highway Plus. Final implementation of shop floor data acquisition programs on the Tray Pack line were accomplished and documented in Technical Working Paper (TWP #103), "Data Acquisition and Monitoring of the Tray Pack Line", Appendix 4.6. Programs were written to automatically acquire temperature and pressure data from the Tiromat controller and to display trending information on the FIXDMACS view node. In addition, connectivity to the factory database over Ethernet was established in order to automatically log information to the Oracle database. These capabilities were demonstrated during the Annual Contract Briefing on March 8, 1995.

In the 2nd quarter of 1995, additional programs were developed for the MRE pouch line for the acquisition of production data, in-process quality control data, and line stoppage/fault diagnosis. The implementation of FIX DMACS to the MRE Pouch line is documented in Technical Working Paper (TWP #109) "MRE Pouch Line: Automatic Data Collection and Display Development", Appendix 4.7.

3.2.3 Software Development and Implementation of Database (3.5.3)

This task item was responsible for implementing database functions for the demonstration runs. During the implementation, there was continuous debugging and upgrading as the project team interacted with the user group in the plant. The final implementation of the materials management module during this phase was documented in Technical Working Paper (TWP #101), "Material Management for Raw Material and Finished Goods: Database Design and

Implementation", Appendix 4.5.

3.2.4 Documentation and Training of Personnel (3.5.4)

Personnel requirements for operating the MRE Pouch Line for Demonstration runs was included in Phase I Task 3.3.6 reported above. In, the Demonstration Runs described below, Section 3.2.5, line operating personnel consisted of the permanent CRAMTD plant operators and the CRAMTD engineers who participated in the equipment development and testing. Included was an operator for each piece of filling equipment, the rack loader, and the packaging line.

Temporary laborers were hired to move material from the warehouse to filler hoppers and to move filled crates to the retorts. These laborers received 2 days of training prior to the runs.

Quality control inspection was minimal during the demonstrations and relied on the CRAMTD Quality Assurance Specialist and the Graduate Students who participated in the computer interface and operator screen developments.

3.2.5 Conduct Demonstration Runs (3.5.5)

The integrated systems for the CRAMTD Tray Pack Line and CRAMTD Pouch Line were successfully demonstrated in part and as a whole at Annual Contract Briefings on November 18, 1993, March 8, 1995, and June 19, 1996, as well as during an industry/academic conference on April 28, 1994.

Since beginning in February 1996, production under the CAFT/CORANET Developmental Manufacture Program has reached approximately 10,000 units of Macaroni & Cheese in 6-lb polymeric, preformed tray containers filled and heat sealed on the Tray Pack line (with the Raque Heat Sealer replacing the Yaguchi Metal Can Seamer). Performance data for the line components as well as the data collection (SPC) portion of the "Centralized Control Station" is being collected under the CORANET Demonstration Contract.

A cost share partner (production customer) is actively being sought to begin Developmental Manufacture on the Pouch, horizontal form-fill-seal line. Operations on the Pouch line would provide experience and performance data for the full functionality of the "Centralized Control Station".

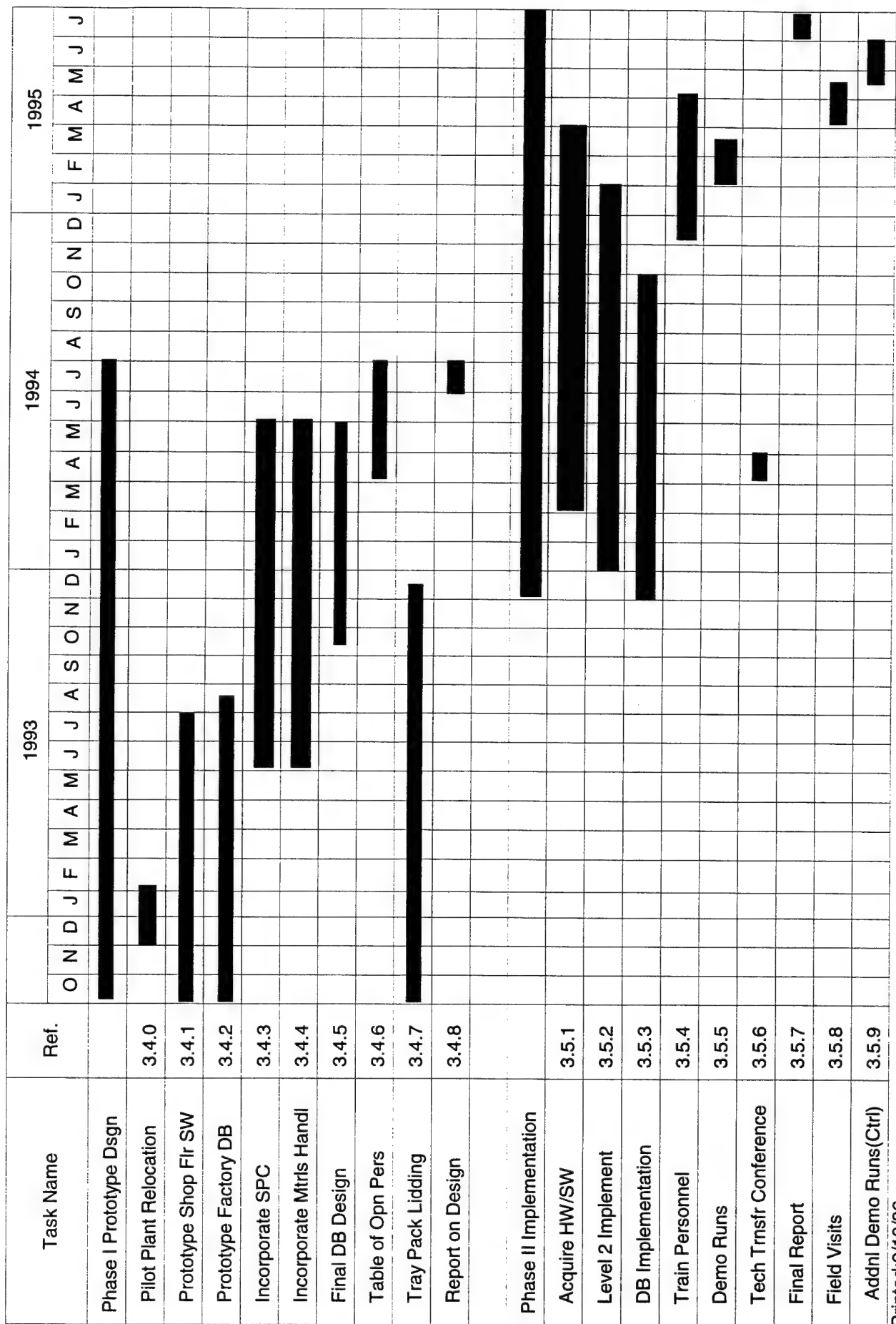
3.2.6 Conduct a Conference for Information Exchange (3.5.6)

In conjunction with The National Science Foundation, a joint industry/academic conference was held in April, 1994, entitled: "Computer Integrated Manufacturing in the Process Industries, CIMPRO '94". Approximately 130 individuals from industry, academia, and government attended. There were over 80 talks, including technical presentations on CRAMTD developments, Conference Program attached as Appendix 4.8. Approximately 60 participants toured the CRAMTD plant and were given demonstrations on the MRE pouch and Tray Pack lines.

4.0 Appendix

- 4.1 Figure: "Time & Events and Milestones"
- 4.2 Specification for Control System for Horizontal Form-Fill-Seal Production Line
- 4.3 "Quality Assurance for Raw Materials and Finished Goods: Database Design and Implementation", TWP #87
- 4.4 "Level 2 Automation of Tray Pack Line", TWP #88
- 4.5 "Material Management for Raw Material and Finished Goods: Database Design and Implementation", TWP #101
- 4.6 "Data Acquisition and Monitoring of the Tray Pack Line", TWP #103
- 4.7 "MRE Pouch Line: Automatic Data Collection and Display Development", TWP #109
- 4.8 Conference Program, "Computer Integrated Manufacturing in the Process Industries, CIMPRO '94", April 1994, New Brunswick, NJ

**Figure 1 - CRAMTD Short Term Project #16
Implementation of Integrated Manufacturing
Projected Time & Events and Milestones**





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July 27, 1994

Mr. Russell Eggers
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Defense Logistics Agency
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Dear Russ:

Enclosed is a copy of the "REPORT ON PROPOSED INTEGRATION OF MRE POUCH LINE FOR DEMONSTRATION RUNS". The Recommendations Section includes four alternatives for the MRE demonstration runs at the end of Phase II STP #16. All of the alternatives include the need to acquire a "production line controller", which has a lead time of about six months from date of order. The cost of implementing the production line controller is \$165,000. With the attached report, we are requesting approval be granted to write a subcontract for \$165,000 to initiate development and installation of a production line control system for the MRE pouch line.

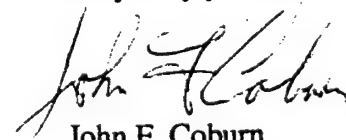
For the production of placeables-only, we explored the possibility of expanding the program in the Tiromat PLC to incorporate some of the controls. This was discarded as an option since it would overload the Tiromat controller. In conversation with representatives of T.W. Kutter, it was recommended that the degree of integration of the Tiromat with other machines as described in the report be done in a separate production line controller.

The proposed production line controller gives CRAMTD maximum flexibility in production operations on the shop floor. It will eventually be possible to use this control unit as a central point of control for the polymeric tray line. In effect, future expansion of this MRE production controller will give it the capability of a controller for the entire shop floor.

Regarding the four alternatives, CRAMTD is presently proceeding consistent with Alternative 3 (Production of both placeables and pumpables). If resources, including time, prove insufficient, we would recommend moving to Alternative 1 (placeables only). On the other hand, if additional resources become available, and/or progress becomes faster, we would recommend moving toward Alternative 4 (addition of in-process data logging and database modules).

cc: T. Boucher
CRAMTD Technical Committee

Very truly yours,



John F. Coburn
Director, CRAMTD

**REPORT ON PROPOSED INTEGRATION OF MRE
POUCH LINE FOR DEMONSTRATION RUNS**

**A Planning Document from CRAMTD
Technical Steering Committee**

1.0 INTRODUCTION

This report addresses Task Item 3.4.8 of STP 16, "Implementation of Integrated Manufacturing". That task item requires a report at the end of Phase I of STP 16 that recommends the integrated design and controls to be implemented and used for the Phase II demonstration runs. Phase II demonstration runs are to be made on the MRE pouch line. Therefore, this report addresses the integrated design and controls for that line.

This report is divided into three main sections. Section 2 addresses equipment requirements as well as automation and data acquisition on the production floor. It describes hardware and software required to demonstrate an integrated production system as well as the functional and worker requirements for that demonstration.

Section 3 of this report addresses database support for overall management control at levels 3 and 4. Here we are primarily concerned with those database functions that can be demonstrated as part of an integrated operation.

Section 4 contains a discussion and provides a recommendation.

2.0 LEVEL 2 AUTOMATION OF MRE FILLING AND SEALING LINE

This section covers the operation of the MRE Pouch Filling and Sealing Line at Level 2 automation. Level 2 automation is limited to the automatic coordination of the equipment along the line and the automatic data collection up to the production line controller.

2.1 CURRENT LINE LAYOUT AND COORDINATION OF EQUIPMENT

Figure 1 is the production line layout for the MRE pouch line for producing products requiring multiple filling steps as well as one step placeable products. Equipment not shaded is currently installed; equipment shown as shaded is proposed for acquisition or is currently being procured. Equipment currently installed includes filling equipment and associated conveying, a Tiromat horizontal form-fill-seal (FFS) machine, and a videojet printer.

There are four machines used for filling. The Solbern volumetric filler provides a beef fill and the FEMC filler provides a vegetable fill for the MRE beef stew product. A conveyor and cup dumping system provides material handling between these machines and the Tiromat. The Oden Filler, a rotary positive displacement pump filler, is used to provide a liquid fill. An Adept PackOne robot and associated vision system provides the capability to fill placable products.

The Tiromat horizontal form-fill-seal machine is a four station intermittent motion machine. The first station forms the bottom side of six pouches from roll stock. The second station is a filling station. The third station is a sealing station at which a top layer of roll stock is heat sealed to the filled bottom pouch. The fourth station is a punching station, at which the six filled and sealed pouches are cut from the roll stock.

The Videojet printers are positioned in-line just before the punching station. They code the pouch with product and production information.

There currently exists some coordination of equipment along the production line. The product transfer system, where cups are filled with meat and vegetable and dumped into pouches, is coordinated with the operation of the Tiromat. Each index of the Tiromat presents six pouches for filling. A signal from the Tiromat controller to the product transfer system controller tells the cup dumper to fill the six pouches. A return signal from the product transfer system controller to the Tiromat controller tells the Tiromat that the fill is complete and an index of the Tiromat can begin.

The Adept PackOne robot is also coordinated with the Tiromat. The robot is used for loading placables. When the Tiromat has indexed six pouches for placable filling, the Tiromat provides a signal to the robot. The robot goes through its filling cycle and, when complete, provides a return signal to the Tiromat controller to indicate it may index six pouches again.

The Oden filler consists of three rotary positive displacement pumps controlled by a digital controller encoder. The Oden filler is used for gravy. The Tiromat controller currently provides a signal to the Oden filler when it wants it to go through its liquid fill cycle. There is a return signal provided from a relay on the Oden.

The Videojet printer is also coordinated with the Tiromat index cycle. The Tiromat PLC provides a signal when the index begins. An encoder wheel on the Videojet printer rides on the pouch film and the printed text is positioned with reference to the encoder wheel.

2.2 PROPOSED EXPANSION OF PRODUCTION LINE EQUIPMENT

In this section we describe new production line equipment proposed to be added to the current existing equipment described in section 2.1. These are the shaded equipment shown in Figure 1. In order for the line to operate continuously in a production mode for the production of Beef Stew and Ham Slices, this equipment is required.

The product feeders provide material replenishment to the Solbern filler and the FEMC filler. When filled, these feeders can provide material for an hour of continuous production at 100 pouches per minute of the beef stew product. At that line speed, these

feeders must be replenished at least once per hour. Appendix A provides a technical description of these feeders. The current estimate of installed cost is \$50,000.

The checkweigher at the exit of the Solbern filler is to be a Hi Speed Checkmate. This machine has its own controller for data logging and its own statistical package for computation. It has feedback capability to make discrete adjustments, such as reject diversion, and continuous adjustments, such as servo motor adjustments for control of the Solbern cup height. It can be interfaced with upper level controllers and computers for CIM integration. Appendix B provides a technical description of the Hi Speed Checkmate. The current estimate of installed cost is \$35,000.

The inspection/infeed conveyor is required for on-line quality control of visual pouch defects and for loading the retort tray loader. Pouches being discharged from the Tiromat will be examined visually for obvious defects. Acceptable pouches will be placed in a lane going to the retort rack loader. Defective pouches are taken off the line and placed in a partitioned bin. Later, these are sorted and classified. Appendix C provides a technical description of the inspection/infeed conveyor. The current estimate of installed cost is \$50,000.

The retort rack loader provides the means for loading of pouches into a retort crate. It consists of two stations. The loading station accepts pouches from the infeed/sorting conveyor and presents them to operators who load them into retort racks. When loading a tray is complete, a new tray is automatically acquired from the empty tray station. The filled tray is indexed down one level in the crate and the empty tray is installed for loading. This continues until a full crate is loaded. Crates are manually loaded and unloaded from the retort tray loader and filled crates are sent to the retort operation. Appendix D provides a technical description of the retort rack loader. The current estimate of installed cost is \$50,000.

2.3 LEVEL 2 AUTOMATION CONTROL STRATEGY

Under CRAMTD Phase II, demonstrations will be conducted on the MRE pouch line. The integration of a 3 step filling operation with two solid fills and a gravy fill requires coordinating all equipment along the line, including the fillers. A specification for this level of integration was developed and is appended to this report as appendix E. Here we summarize the main features of the specification.

- 1) The equipment is rewired so that the entire line can be started and stopped from a central location, the control panel. It will also be possible to operate pieces of equipment locally by switching to a local mode of operation.
- 2) Information displays and readouts will be implemented at a central location, the control panel. This will be done by installing a new PLC that will collect information from the various machines on the line, including the Tiromat PLC.

- 3) All current control interfaces will be housed at one location in a NEMA 4 enclosure. This will include the SMART system of the Tiromat, the Adept robot terminal, and the FIXDMACS view node. It will eventually be possible for the FIXDMACS software to bypass the SMART system and Adept terminal for programming these devices.
- 4) Sensors and bar code scanners for on-line data collection will be installed. One of the bar code scanners will be used to input data on material lots as they are placed into production. Another bar code scanner will be placed at the retort rack loader to identify crates as they are being loaded with pouches. This is part of the lot tracking function.
- 5) It will be possible to download information to the Videojet printer via serial communication port.
- 6) Considerable *in-line automatic data collection* for quality control will be provided under this specification. These are given in detail in the text of the specification, but we list the major items here:

<u>Machine</u>	<u>Data automatically acquired</u>
Solbern Filler	Temperature of beef
Checkweigher	Weight of beef in cup from Solbern
FEMC Filler	Temperature of vegetables
Oden Filler	Gravy temperature
Tiromat	All data currently collected by SMART system
	Differential seal pressure
	Seal plate temperature
	Temperature of pouch ingredients prior to sealing
Retort rack loader	Cage identification for tracking into retort
PLC 5 RF barcode scanner	Mat'l lot number when released to WIP

The implementation of this specification will cost \$165,000. The delivery time is approximately 6 months from the time a contract is awarded. This does not include development work on FIXDMACS, which will be done in-house.

In addition to the level 2 automatic controls given in the specification of appendix E, there is quality control data collection that is done on a sampling basis. Since this data cannot be collected automatically, it will be manually entered into the factory database at the sample intervals. Data that is collected and recorded on the factory floor will be called *on-line QC data*. On line QC data may be automatically collected (in-line data, as in item 6, above), or manually collected and entered at an operator workstation. Samples that are collected manually and taken to the QC lab for analysis will be called *off-line QC data*. This data is entered into the factory database from a workstation in the QC lab. The on-line and off-line QC data that could be collected as part of demonstration runs are shown in Tables 1 and 2.

Table 1
ON-LINE QUALITY DATA COLLECTION

<u>Machine</u>	<u>Data</u>
SOLBERN FILLER	Beef Lot Number Beef Temperature Average Beef Fill Weight Standard Deviation of Fill Weight Average Accepted Fill Weight Standard Deviation of Accepted Fill Weight Percent of Underweight Cups Percent of Overweight Cups Percent of Total Cups Rejected at Checkweigher Cup Depth at Solbern Operator Comment Field
FEMC FILLER	Vegetable Lot Number Vegetable Temperature Fill Weight Average (sample) Fill Weight Standard Deviation (sample) Operator Comment Field
ODEN FILLER	Sauce Lot Number Sauce Temperature Sauce Fill Weight per Nozzle Operator Comment Field
ADEPT ROBOT	Material Lot Number Product Temperature Product Fill Weights Product Thickness Operator Comment Field
TIROMAT	Line Speed Bottom Web Lot Number Top Web Lot Number Pouch Preform Size Maximum Vacuum Vacuum Time Sealing Time Sealing Temperature Sealing Pressure Operator Comment Field

INFEED CONVEYOR	Defect Catagory: seal wrinkles, abrasion, delamination, tears & cuts, leakers, inadequate seal width, other. Operator Comment Field
RETORT RACK LOADER	Retort Crate Number Start Time of Fill Number of Layers Filled Operator Comment Field

Table 2
OFF-LINE QUALITY DATA COLLECTION

<u>Machine</u>	<u>Data</u>
FEMC FILLER	Product Blend Ratio
ODEN FILLER	Liquid Viscosity
TIROMAT	Residual Gas Internal Pressure Seal Width Seal Strength Operator Comment Field

2.4 FUNCTIONAL REQUIREMENTS AND TABLE OF OPERATING PERSONNEL

The following tables represent our current estimates of worker requirements to run the MRE pouch line at level 2 automation for a placeable product (Ham Slices) and for Beef Stew.

Table 3
WORKER REQUIREMENTS BY FUNCTION
FOR HAM SLICES AT 50 POUCHES PER MINUTE

<u>FUNCTION</u>	<u>WORKERS</u>
Materials Handling from Warehouse to Production Line	1
Product Feeding to Robot Conveyor	3
Inspection before Sealing	1
In-line Pouch Inspection at Sorting Conveyor	3
Retort Rack Loading and Material Handling to Retort	3
Quality Control Technician	1
Overall Supervision of Line	<u>1</u>
TOTAL	13

Table 4
WORKER REQUIREMENTS BY FUNCTION
FOR BEEF STEW AT 100 POUCHES PER MINUTE

<u>FUNCTION</u>	<u>WORKERS</u>
Materials Handling from Warehouse to Production Line	1
Product Feeder Materials Handling	1
Oden Filler Supervisor/Cup Dumper Operator	1
Filling Line Operator	1
Inspection Before Sealing	2
In-line Pouch Inspection at Sorting Conveyor	6
Retort Rack Loading and Materials Handling to Retort	4
Quality Control Technician	1
Overall Supervision of Line	<u>1</u>
TOTAL	18

3.0 DATABASE FUNCTIONS AT LEVELS 3 AND 4

This section describes database functions that could be implemented to support the Phase II demonstrations. In some cases these functions can run independent of MRE pouch line operation and in some cases they are linked to the line operations through FIXDMACS.

3.1 MATERIALS CONTROL

The control of raw ingredients and finished product are, from an information point-of-view, independent of the operation of the line. The raw material control function begins when materials arrive at the plant and ends when materials enter work-in-process. The finished goods control function begins when product exits work-in-process and ends when product is shipped.

Currently, this portion of the database is close to being complete. It can be used in conjunction with a working demonstration as materials are relieved from the warehouse and moved into production.

3.2 RAW MATERIAL AND FINISHED GOODS QUALITY CONTROL

The database for quality testing of raw material and finished goods is nearing completion in its implementation in CRAMTD and is currently being used by QC personnel. This database is used in the quality laboratory for recording test results on raw materials and finished goods. As in the case of materials management, this database functions independent of the operations on the factory floor.

3.3 WORK-IN-PROCESS DATA COLLECTION

As shown in Tables 1 and 2, integration at level 2 includes the collection of data both on-line and off-line. On-line data (Table 1) is collected directly by the production line PLC. This data can be acquired through the FIXDMACS shop floor control software and can be uploaded to the factory database. At present there has not been any development done for the collection and storage of work-in-process data.

There are basic categories of work-in-process data collection that are designed into the data collection system of the production line controller. They can be broadly categorized as in-process quality control information, such as fill weights, and material tracking information, such as material lot numbers.

The acquisition and logging of work-in-process quality control data lends itself very well to a demonstration of integrated manufacturing. This is a potential area of development for Phase II of STP 16 and could be used as part of the demonstrations.

4.0 DISCUSSION AND RECOMMENDATIONS

The integrated design described in this report is judged to be the most effective way to demonstrate MRE line integration. Current controls on the line are minimally sufficient for coordinating the filling equipment with the Tiromat and, with the exception of the Tiromat, does not include the ability to collect on-line data. Furthermore, the inclusion of the infeed/inspection conveyor and retort rack loader are required for continuous running of the line and they will have to be integrated into the overall control scheme.

For the demonstration runs at the end of Phase II, there are several possibilities that can be considered. Table 5 orders these possibilities from a one-step placeable filling operation for Ham Slices to a three-step filling operation for Beef Stew. For each of these alternatives we show the additional capital equipment acquisitions necessary for the demonstration runs. The following is a discussion of each of these alternatives.

Alternative 1 is a demonstration of filling placeables only. Current interest in expanding the number of MRE placeables suggests that there will be more interest in demonstrating technical developments in this area at this time. Under alternative 1, we would demonstrate information systems that have been completed to date rather than to plan to add new data modules at this time. This is the least cost option with additional capital equipment acquisitions of \$265,000.

Alternative 2 is the same as alternative 1 with the addition of in-process data logging from the production line controller to the factory database. Under this alternative it will be necessary to add database modules for in-process quality control and material tracking between now and the demonstration runs and, when the production line controller is installed, to develop the FIXDMACS programs that will automatically acquire the data from the production line controller.

Alternative 3 is the production of the Beef Stew product. This would demonstrate the integration of the full line for pumpables. Under alternative 3, we would demonstrate information systems that have been completed to date rather than to plan to add new data modules at this time. The required new capital acquisitions total \$350,000.

Alternative 4 is the same as alternative 3 with the addition of in-process data logging from the production line controller to the factory database. This option is the most difficult to implement within the time frame of the existing contract. Once the production line controller is installed, a period of debugging and tuning the operation of the line will be required. We would anticipate that this will be more involved in the case of Beef Stew production than Ham Slices due to the additional filling operations. Hence, there may be competing access for the production line and its controller during the period prior to the demonstration, making it difficult to achieve both production and data logging objectives.

A constant that runs through these four alternatives is the need to acquire the production line controller, which has a lead time of about six months from date of ordering. For the production of placeables only, we explored the possibility of expanding the program in the Tiromat PLC to incorporate some of the controls as given in Appendix E. This was discarded as an option since it would overload the Tiromat controller. In conversation with representatives of T.W. Kutter, it was recommended that the degree of integration of the Tiromat with other machines as described in this report should be done in a separate production line controller. This is consistent with the recommendations of this report.

The cost of implementing the production line controller is \$165,000. This includes significant development cost as a first time project. It is difficult to estimate how much a second or third copy would cost and we would not be able to provide a dollar figure at this time. However, there is considerable interest at this time in the use of the horizontal pouch for placeables. Therefore, we are requesting that T.W. Kutter provide a quote for the integration of the proposed line at level 2 automation with the Tiromat using a production line controller for placeables only. This quotation will be reported separately when it is received.

It should be pointed out that the proposed production line controller of appendix E gives CRAMTD maximum flexibility in production operations on the shop floor. It will eventually be possible to use this control unit as a central point of control for the polymeric tray line and Enersyst oven. In effect, future expansion of this MRE production line controller will give it the capability of a controller for the entire shop floor.

The conclusion of this report is that we should proceed with the development of the production line controller and conduct the demonstration after the system is installed. With this report, we are requesting approval be granted to write a subcontract for \$165,000 to initiate development and installation of a production line control system for the MRE pouch line.

Table 5
ALTERNATIVE CONFIGURATIONS FOR
PHASE II DEMONSTRATION RUNS

ALTERNATIVE 1

Basis for Demonstration:

- Level 2 Automation: Ham Slice production at 50 pouches/min.
- Level 3/4 Automation: Materials control from warehouse to WIP; finished goods control from WIP to warehouse; materials and finished goods quality control.

New Capital Acquisition:

Production Line Controller	\$ 165,000
Infeed Conveyor	50,000
Retort Rack Loader	<u>50,000</u>
	265,000

ALTERNATIVE 2

Basis for Demonstration:

- Same as Alternative 1, with additional development work at level 3/4 to incorporate logging quality control and material tracking data up to database.

New Capital Acquisition:

- Same as Alternative 1.

ALTERNATIVE 3

Basis for Demonstration:

- Level 2 automation: Beef Stew production at 100 pouches/min.
- Level 3/4 automation: Material control from warehouse to WIP; finished goods control from WIP to warehouse; materials and finished goods quality control.

New Capital Acquisition:

Production Line Controller	\$ 165,000
Product Feeders	50,000
Checkweigher	35,000
Infeed Conveyor	50,000
Retort Rack Loader	<u>50,000</u>
TOTAL	350,000

ALTERNATIVE 4

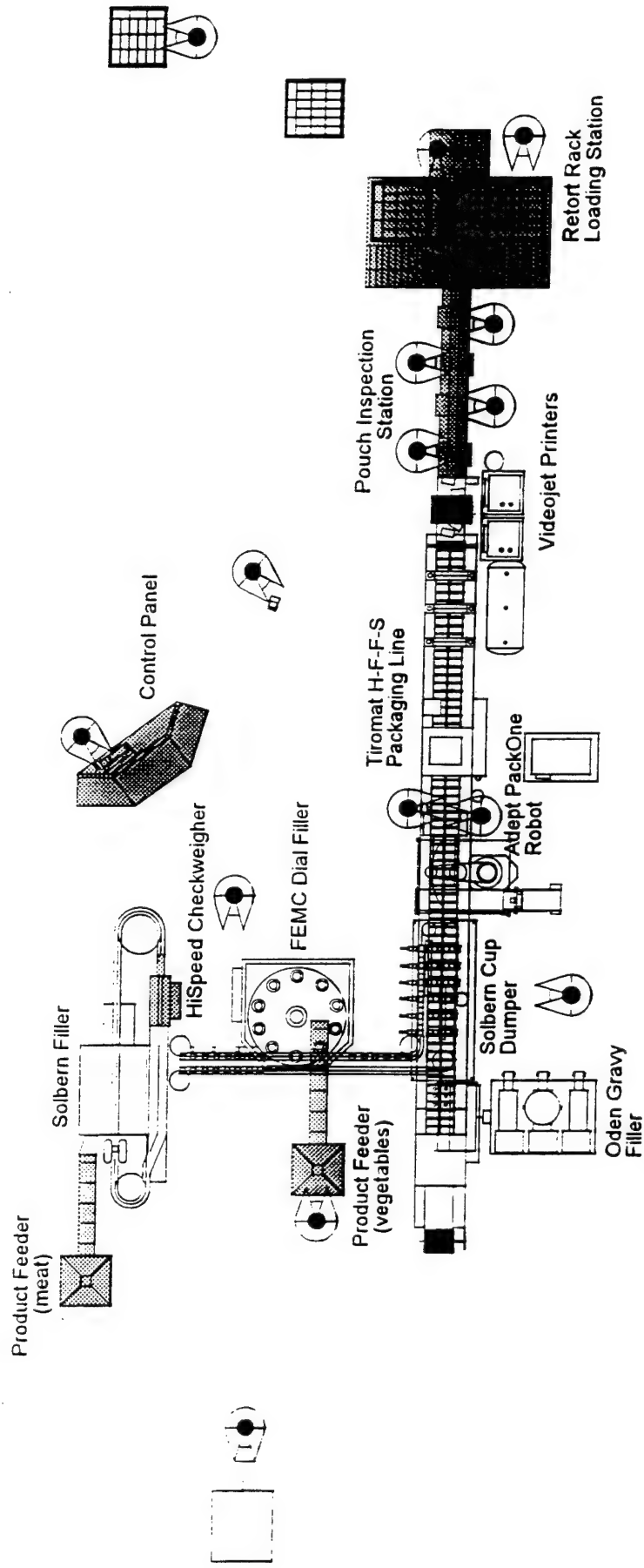
Basis for Demonstration:

- Same as Alternative 3, with additional development at Level 3/4 to incorporate logging quality control and material lot tracking data up to database.

New Capital Acquisition:

- Same as Alternative 3.

Integrated MRE Production Line



Integrated Production Line
Retort Loader Concept B
June 6, 1994

Equipment not
Installed

Figure 1

APPENDIX A

PRODUCT FEEDERS

Product Feeders:

Product from the warehouse will be dumped into floor hoppers on the product feeders and flighted conveyors will bring the product up to the filling machine hoppers. A level control switch in the filling machines will indicate that more product is needed and start the product feeders. A level control in the floor hoppers will alert the operator that product level is low in the hopper.

KAMFLEX

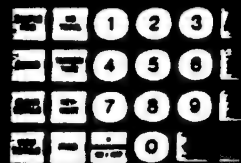


APPENDIX B

CHECKWEIGHER

CHECKMATE

Full statistic.
at the line.
in real time.



CHECKMATE™

The Higher Intelligence

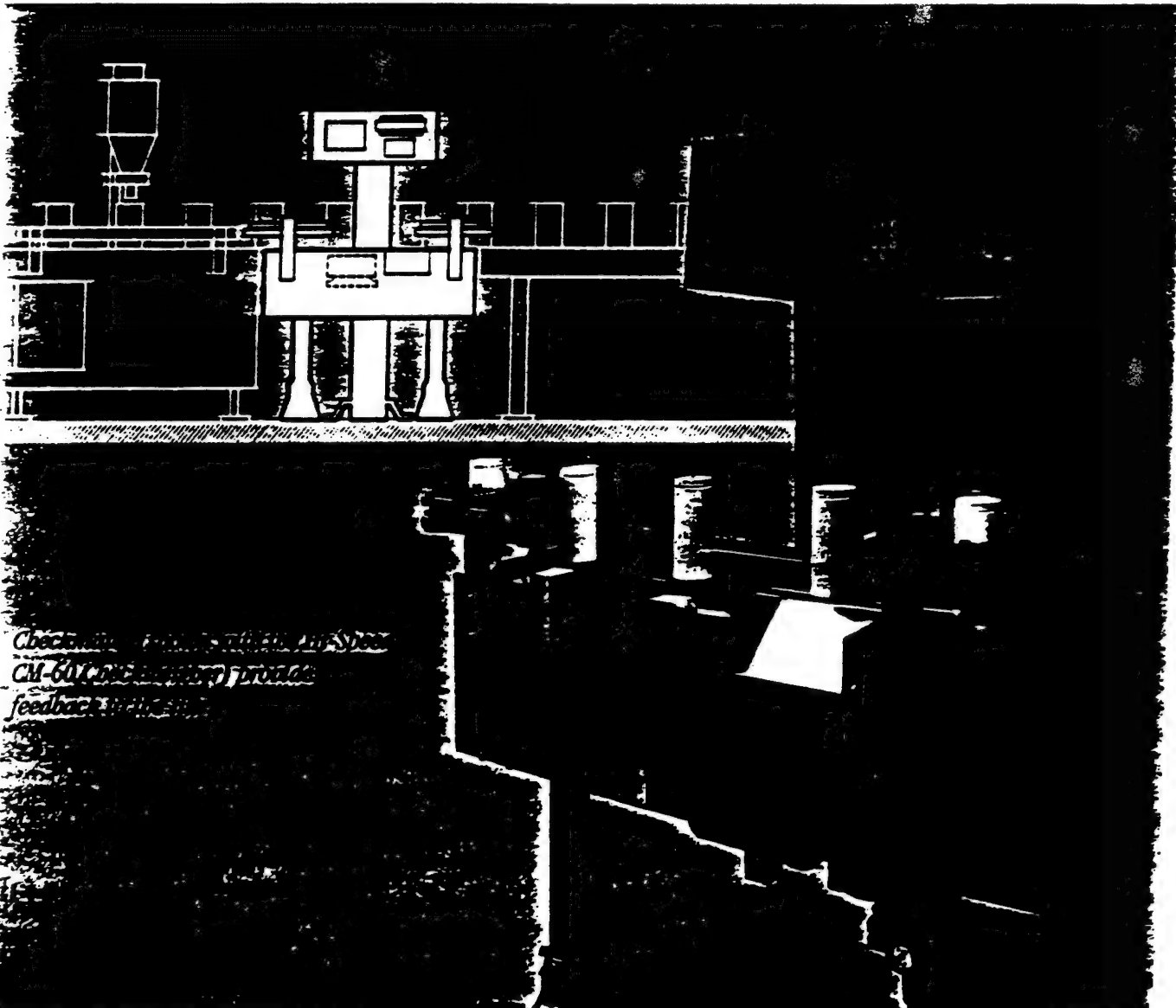
There isn't another checkweigher control available today that can out-perform Checkmate. Checkmate provides answers for those who want total information and tighter control of their processing and packaging lines.

Checkmate gives you the unsurpassed accuracy you expect from Hi-Speed technology *plus* complete statistics at the line as it happens — no off-line calculations, no delays.

There's no need to stop production to make adjustments either. Checkmate's full range of statistics allows you to make accurate filler adjustment decisions, and provides automatic feedback directly to the filler.

Checkmate's 50 product set-up provides instant access to all preprogrammed product parameters. Use Checkmate to support up to 6 independent scales within the same mainframe, or in close proximity. Checkmate's versatility and capabilities are adaptable to your application and will integrate with most Hi-Speed checkweighers.

To further enhance total statistical process control, Checkmate's full bidirectional communications capabilities allow interface with Hi-Speed's EZWAY™ Data Collection System.



Checkmate's full range of statistics at the line. CM-60 (Checkmate) provides feedback to the filler.

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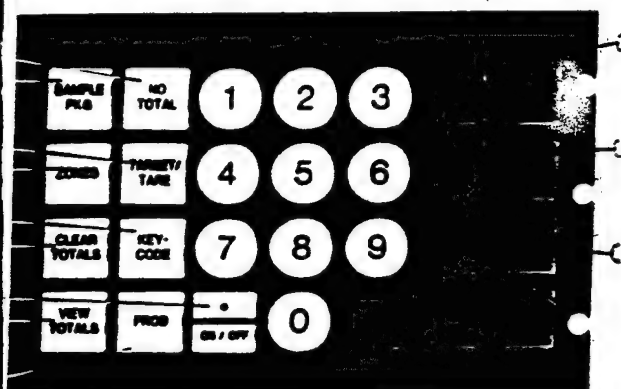
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It's all at your fingertips with

CHECKMATE

Input is handled through menu selection, direct key access, and soft keys. Checkmate communicates back to you in simple, direct language. Direct access keys are clearly labeled and color coded: yellow Set-Function keys provide single-stroke access to the most commonly used operator functions and red keys are Menu/Control keys. Keys are environmentally sealed and have alphanumeric capability.



No Total — turns off counters yet retains count information when you run a test package.

Sample Package — automatically ejects up to 25 packages and displays package weights for verification without stopping production.

Target/Tare — enter target weight and associated tare.

Zones — view and/or change current product point limits.

Key Code — provides 3 levels of security to facilitate limit accessibility.

Clear Totals — zeros counts selected product zones, and resets statistics.

Decimal — enter decimal point position.

View Line Summary Screen — call up count and percentages by zone: accepts, underweights, overweights and total weight.

Product — instant recall of any of 50 products programmed.

On/Off — rejector status by zone and decimal point.

Calib. — operator prompted machine set-up.

Normal Display — shows current set-up limits on Checkweigher Screen.

Menu — access to all functions.

Cancel — deletes last entry.

Cursor Keys — for scrolling through menu or viewing related screens within one category of information.

Enter — enters data into memory.

Easy to Program.

Checkmate's LCID display and 80 x 25 graphic display indicate acceptable weights as well as gross under and overweights. The special non-glare panel gives only the information you need, when you need it — no distracting additional prompts. The display shown below is fully illuminated for demonstration purposes.



Zone Indicator Displays

- Zone 1 (Red) gross underweight
- Zone 2 (Yellow) just under
- Zone 3 (White) accept
- Zone 4 (Blue) just over
- Zone 5 (Green) overweight

Weight Mode Indicator

Deviation from Target or Actual weight readout mode.

1 1/8" LCID Weight Display

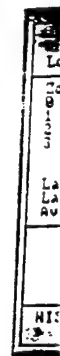
Shows actual net weight of your product or variation as a plus or minus from target.

Weight Unit Indicator

Displays weights in grams, kilograms, ounces, or pounds.

System Status Indicators

- **Sample Package (Orange)** — automatically ejects package(s) from the line and displays the weight for operator verification.
- **No Total (Orange)** — indicates that the counters are "off" during set-up and calibration.
- **Good Rezero (Green)** — indicates that the scale is automatically rezeroed every time there is a gap of one or more packages in the production flow.
- **Needs Rezero (Red)** — immediately alerts the operator to excessive product build up on the scale or that automatic rezero is overdue.
- **Package Spacing (Red)** — alerts operator that packages are too close together for accurate weight.
- **Scale Noise (Red)** — alerts operator of excessive internal and/or external interference i.e., vibration, air currents, and unstable product transfer.

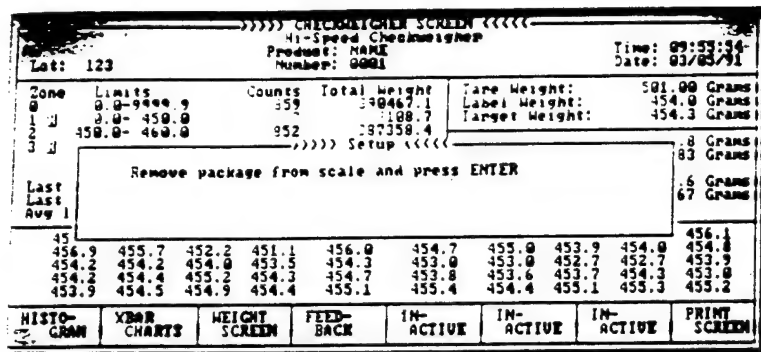


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Heckweiger Screen



Screens providing running statistics or graphic representations are accessed by direct keys or through menu selection. The sample screen above is the Checkweigher screen, also known as the Normal Display. It shows the checkweigher settings and production weights for a specific line (notice product name, lot number, and label weight display capability). The set-up values shown are for purpose of sample only (See front cover for full view Checkweigher screen). A small insert window gives the user step-by-step instructions for set-up and calibration. The window (shown above) is called up by pressing the "calibrate" key.

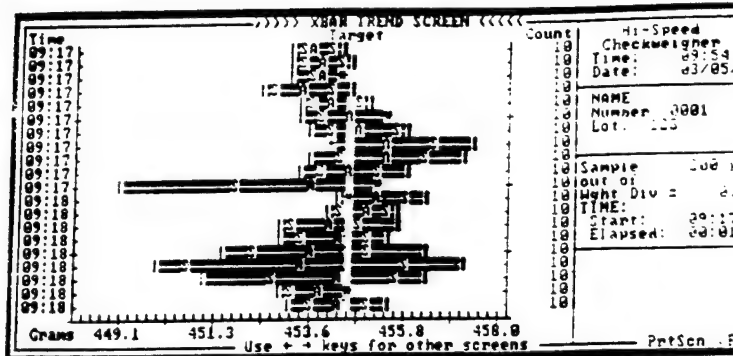
Soft Keypad



Each key of the soft key pad (F1-F8) is aligned below designated functions shown at the bottom of the Beckweigher and Weights Screens. Other screens include: Histogram, XBAR, Summary, Statistics, Feedback, Screen Setup, Product setup, and Calibration parameters. Each screen may be accessed by a single stroke on the soft key pad. The software you select for your application will determine how many levels of information appear on each screen.

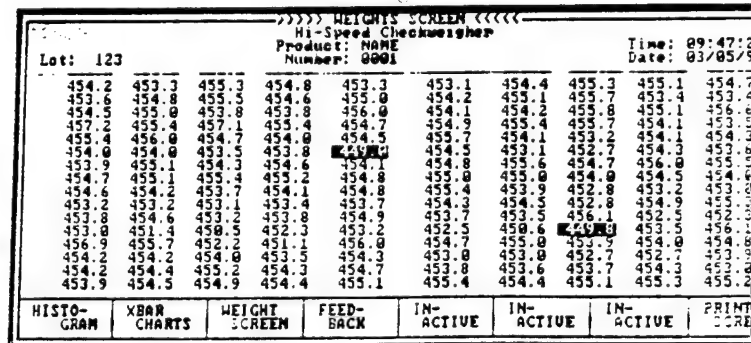
Easy to Understand.

XBAR Trend



See averages, standard deviation and range as individual XBAR charts, as well as XBAR trend chart (composite display instantly. No waiting for Q.C. reports or printouts. No time or product lost before appropriate line adjustments can be calculated and made. XBAR control chart sampling, based on time or count, is displayed showing user-entered control limits and interval data.

Weights

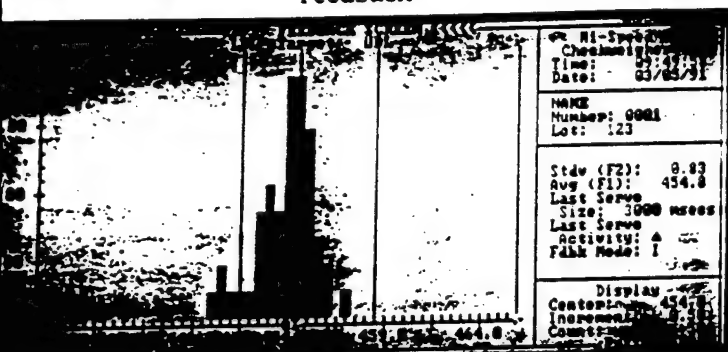


160 weights are displayed at one time. Rejected weights are highlighted, making it easy to see how the weights are running.

*The software you select for your application
will determine how many levels
of information appear on each screen.*

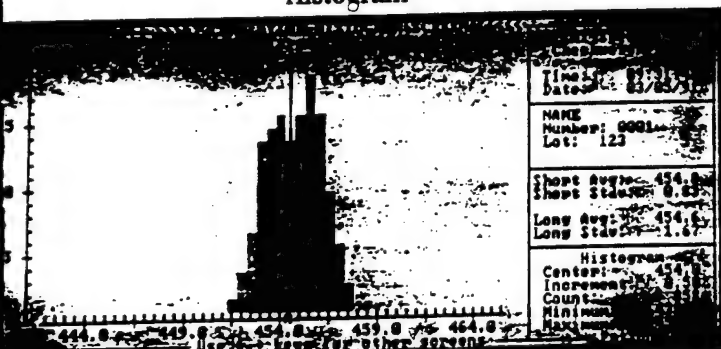
Concise, running statistics put you in complete control.

Feedback



This screen provides a visual indication of decisions being made regarding feedback calculations and servoing. Feedback parameters are set and Feedback Target Weight is determined based on standard deviation, not just averages. No waiting for Statistical Process Control calculations and reports. Feedback filler automatically, accurately, and instantly.

Histogram



Easy to understand histograms show short term and cumulative product distribution instantly. Calculations are not necessary — there are no delays for information reaching the line.

Checkmate Basic

Checkweigher Statistics include:

- Package Counts by zone, Total Weight by zone, Averages, and Standard Deviation displayed on run and summary screens.
- Efficiencies and Distribution Percentages are shown on line summary screens.
- Rate Counter displayed on run screen.

Checkmate Screen Options:

- Histogram Package. Basic Checkweigher Statistics plus Graphic Histogram Representation of Short-term Product Distribution and Cumulative Product Distribution.
- XBAR Screens and Summaries SQC Package. XBAR screens and summaries: Basic Checkweigher Statistics plus Graphic XBAR representation of Averages, Standard Deviation, Range, and Trends (a composite of all three).
- Feedback Package. This includes the Histogram Package, feedback screen and filler interface.
- Multihead Statistics Package. Basic Checkweigher Statistics plus multihead screen.

Call: 1-800-836-0836

HI-SPEED CHECKWEIGHER, CO., INC.
5 Barr Road
Ithaca, New York 14850
1-800-836-0836 / 1-607-257-6000
Fax: 1-607-257-5232

HI-SPEED®

CHECKMATE™

General Specifications

Checkmate Features:

- 50 product setup, (optional 100)
- 3 to 5 weight zones
- Handles in excess of 600 ppm
- Handles up to 6 concurrently serviced weigh platforms (optional)
- ACTP – built in automatic checkweigher test procedure
- User programmable Keycode password security (multi-level)
- Keyswitch security
- Large (1 1/8"), easily viewable digits
- Weights displayed in gross, net or deviation from target in ounces, grams, lbs., kilograms, or no units.
- Alphanumeric user display for data entry, display of production and set-up data
- Enhanced user friendliness by use of full size 200 x 640 LCD display and menu selections
- Single key data access to many functions including soft keys for expanded flexibility
- Time of day/date calendar function

Enclosure:

- Dimensions: 12"H x 24"W x 15"D
- Cold rolled (NEMA 12) or stainless steel (NEMA 4X) (optional)
- Suitable for hazardous environments (optional)
- Washdown (optional)

Operating Environment:

- Temperature: 0° – 38°C / 32° – 100°F
- Humidity: 100% noncondensing
- Designed for continuous operation
- EMI, RFI, and ESD protected

Electrical:

- Listed industrial control panel
- 5 VAC ± 10% – single phase, 50/60 Hz.
- Rated for 1 amp (50 VA power rating)
- Other voltages available
- Microcomputer regulating transformer required

Self-Diagnostics:

- Memory test, A/D functional test, display check (all off and all on), power indicators, input-output indicators, I/O test.

Auto-Rezero:

- Rezero automatically instant or

Technology:

- Single board microcomputer with 16 bit industry standard microprocessor and coprocessor for enhanced processing rates
- EPROM program memory
- Battery backup RAM memory for set-up data and long-term accumulated data
- 3 channel serial data output RS232, RS422, or current loop
- Bidirectional EZWAY communications link

Scale:

- Self-checking scale operation display indicates:
 - Good rezero
 - Needs rezero
 - Scale noise
 - Package spacing errors

Accuracy:

- Unsurpassed weight signal processing produces the purest weight signal possible with Hi-Speed's exclusive patented algorithms
- No potentiometer adjustments required
- Gain, filtering and timing automatically set and optimized for each product.

Checkmate Options

Rolling Statistics Sizes:

- N1 Average Size: 10-999
- N2 Std. Dev. Size: 25-999
- N3 Histogram Size: 50-999

Statistical Limits:

- Provides alternative range for processing statistics
- Fully user enterable, default = 0 - 9999.9

Multihead Statistics:

- 60 head capability
- N1 (Short term average) for each head: 10
- N2 (Short term std. dev.) for each head: 25
- Last 14 weights displayed for each head

Tare Gross:

- Dedicated bi-directional communication link
- Tare-Gross set-up screen
- Out-of-sync alarm and window

Floating Zone:

- Confirms correct piece counts on product where individual weights fluctuate with

Feedback:

- Dynamic control of servo activated fillers
- Control based on either independent or block mode statistical calculations
- Histogram-type display showing servo activity and product distribution
- Full user control over upper and lower deadband limits, z (standard deviation multiplier), feedback target weight upper limit, average sample size (F1), standard deviation sample size (F2), and weight for correction and optimizing feedback to minimize product giveaway as filler distribution improves
- Pulse train or timed output
- Remote operator panel optional for timed output

Printer:

- An 80 column parallel printer for full report generation and individual print screen capability via soft key access.

Serial Weight Output Capability:

- This option comes with a setup to print every weight, every N weights, or X weights every Y weights.

EZWAY Statistical Process Control Data Collection System:

- Unidirectional or bidirectional interface with Hi-Speed Controls for real-time production monitoring of all lines from a single location.

HI-SPEED CHECKWEIGHER, CO., INC.
5 Barr Road
Ithaca, New York 14850
1-800-836-0836 / 1-607-257-6000
Fax: 1-607-257-5232



HI-SPEED®

APPENDIX C

INFEEED / INSPECTION CONVEYOR

Inspection/Sorting Conveyors:

The pouches discharging from the Tiromat will first be lightly compressed to 5/8" thickness by a top conveyor over the Tiromat discharge conveyor. Pouches will then go on a dual lane inspection conveyor to be inspected visually. Acceptable pouches will be placed on a single lane overhead conveyor going to the manual retort rack loaders. Rejects will be placed in a partitioned bin opposite the inspector.

APPENDIX D

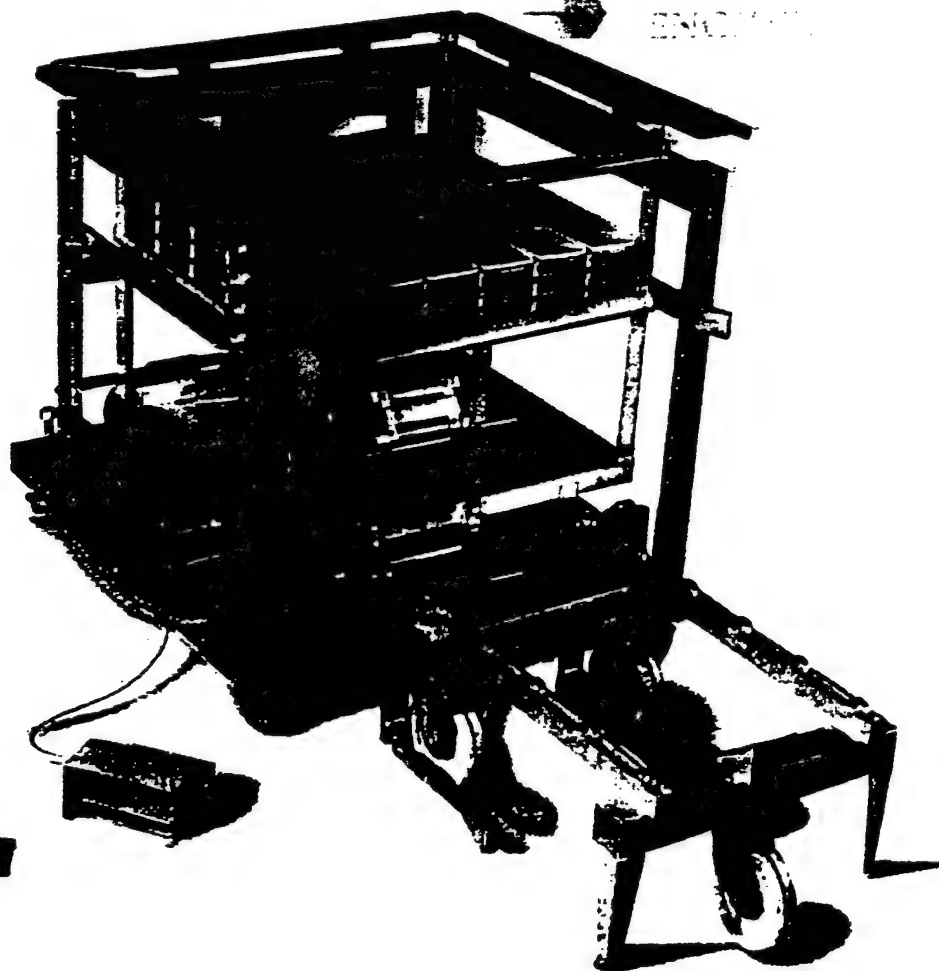
RETORT RACK LOADER



BRENTON
ENGINEERING COMPANY

PORT • LOADING/UNLOADING STATION

Brenton Engineering Company offers a portable Loading/Unloading Station for retort handling needs. This station incorporates a lift table to facilitate manual loading and unloading of retort baskets and can be custom built to meet your retort specifications and needs.



APPENDIX E

SPECIFICATION FOR MRE PRODUCTION LINE CONTROLLER

The State University of New Jersey
RUTGERS
Cook College - Center for Advanced Food Technology
CRAMTD Program

Specifications
For

Control System for Horizontal Form-Fill-Seal Production Line

This specification covers the requirements for a control system that will be used for the CRAMTD program under STP #16 - Implementation of Integrated Manufacturing. This specification includes control panel, PLC, wiring to existing machinery, installation of sensors, and software requirements for the PLC that will be used to coordinate machines on the horizontal form-fill-seal pouch line, while gathering information for data logging. Hereafter, this controller will be referred to as the "production line controller". The machines and their production line layout that are included in this specification are shown in Figure 1.

This specification consists of the following sections:

1. Performance requirements
2. Hardware requirements
3. Software requirements
4. Modes of Operation
5. Documentation requirements
6. General
7. Acceptance
8. Shipping and installation

1.0 Performance Requirements

1.1 Operational Duty. The equipment is to be capable of continuous operation in a typical food production environment. This equipment must operate in a typical wash down area and must withstand the use of non-caustic detergent, bleach and high pressure water cleaning. Cleaning time will be provided daily as required by regulatory agencies (i.e., FDA, USDA) or at least once per day.

1.2 Scan Time. The scan time of the production line controller shall be sufficient to handle all data logging functions and reporting functions to the scada node when the filler and checkweigher are operating at speeds up to 300 cups per minute and the form-fill-seal machine is operating at 110 pouches per minute. The relationship of the production line controller to the scada node and higher levels is shown in Figure 3.

2.0 Hardware Requirements

2.1 The controller hardware shall be a series 5 Allen Bradley PLC with a 5/12 processor or higher, based on the scan time and memory requirements to perform the control and data logging functions as described in section 1.2 and 3.0.

2.2 The control panel shall be a stainless steel floor mounted Nema 4 panel of approximate specifications and layout as shown in Figure 2. Hereafter, this will be referred to as "the panel". It shall have a flange mount main disconnect switch. The following components shall be mounted on the panel.

2.2.1 Control Switches

Push button start/stop contacts for the entire line.

Remote / Local select switches for the following subsystems: Solbern filler, FEMC filler, product feed fillers, checkweigher, Tiromat form-fill-seal machine, Adept robot, Oden filler, Videojet printers, and retort loader.

Selector switches that indicate which combination of three fillers are being used: Solbern dumper, Oden filler, Adept robot.

Interface for entering digital data and obtaining digital readout for set speeds of the following subsystems: Solbern shaker, drum, filler belt, and dumper belt.

2.2.2 Information displays

Digital readout of set speeds in 2.2.1, above.

Tiromat pouch production rate.

Inspection station reject count.

Retort rack loader rate and count.

Lamp on top of control cabinet to indicate status of line: red (stopped), green (running).

Digital readout of the product temperature data being collected by on-line sensors.

2.2.3 Pilot Lights

Product Feeders(2) - Power On (Ready), E-stop, Low Product Level.

Tiromat - Power On (Ready), Running, E-stop, Fault.

Solbern - Power On (Ready), Cycle Start, Pause, E-stop, Product Low Level, Dumper Jam, Dumper Starved.

FEMC - Power On (Ready), Product Low Level, E-stop, Low Speed, High Speed, Back Up Sensor.

Adept Robot - Arm Power, Program Running, Conveyor Start (On), Conveyor Stop, E-stop.

Videojets - Power On (Ready), Head, Print.

Retort Loader - Power On (Ready), E-stop, Pouch jam, No Pouch, No Rack.

Oden - Power On (Ready), Hopper Level, E-stop, Nozzle Fault.

Checkweigher - Power On (Ready), Fault.

Line Air Pressure Alarm
Vacuum Pressure Alarm

2.2.4 Terminal Displays

SMART Workstation and monitor, provided by Rutgers.

Adept Robot Workstation with Monitor and Mouse, provided by Rutgers.

Operator Interface with functions as described in sections 2.2.1, 2.2.2 and

2.2.3. Options quoted separately as follows:

a) A CRT display indicating line status and faults.

b) A touch screen panel view with a graphic display of the line, incorporating functions described in section 2.2.1, 2.2.2 and 2.2.3. Multiple screen levels or windows should display details for each machine.

View Node Operator Interface Workstation and Monitor as specified in Appendix A.

Contractor will provide a NEMA 4 Keyboard. It would be desirable if one keyboard could be used for all workstation interfaces.

2.3 All electrical wiring, connections, control boxes and components shall conform to NEMA 4 standards. Quick disconnects are to be used at all movable machinery. Wiring and conduits are to be off the floor, with a minimum number of drops from the ceiling.

2.4 The terminal CPU's will be mounted within the panel (SMART PDP11, Adept, view node operator interface as specified in Appendix A, and the PLC). All terminals shall have access to their computer disk drives through water tight doors.

2.5 Sensors and bar code scanners for on-line data acquisition shall be provided and installed by the contractor as per items 3.1.1.2, 3.1.3.2, 3.1.5.1, 3.1.6.2, 3.1.11.

3.0 Software Requirements

3.1 The following specifications refer to control and data logging requirements for the equipment shown in Figure 1. This equipment includes the Solbern filler, a checkweigher, FEMC filler, two product feed fillers, Tiromat form-fill-seal machine, Oden filler, Adept robot, Brenton Retort pouch loader, and Videojet printer.

3.1.1 Solbern Filler. The Solbern filler is programmed and operated by an Allen Bradley SLC 500 controller, model 02. It provides open loop control of the cup conveyor, cup transfer system, and the rotating filler drum. The following control functions should be available from the shop floor controller.

3.1.1.1 Production Line Control

Start / Stop: The Solbern filler should be started and stopped from the production line control panel. A return signal should be provided by the Solbern controller to indicate it is running.

Remote / Local operation: A Remote / Local switch should be provided on the production line control panel so that the Solbern filler can be operated under local control of the Solbern controller. When operating under remote control, the Solbern controller start button is overridden by the Solbern start button on the production line control panel. All control functions currently adjustable at the Solbern controller will be adjustable by remote input in the remote mode.

Checkweigher Conveyor: This conveyor should be placed under the control of the production line controller. This conveyor should start when the Solbern starts. Provision should be made to regulate the variable speed drive of this conveyor. If there is a high rejection rate from the Solbern because cups are being recycled empty, it should be possible to regulate this drive to a slower speed.

3.1.1.2 Data Logging

Line Stoppages: The production line controller shall record the source of all line stoppages such that this data can be collected by the scada node.

Low Product Level: The production line controller shall record the existence of a low product level from a sensor in the Solbern filler. This condition shall be used to replenish product from the product feed filler attending the Solbern.

Temperature Sensor: The contractor shall install a non-contact temperature sensor for acquiring the temperature of beef in the Solbern filler. Provision for collecting the data will be made in the production line PLC.

3.1.2 Checkweigher. The Checkweigher weighs filled cups coming from the Solbern filler and either accepts the fill weight or diverts the cup back to the filler because its weight is out of spec. The checkweigher controller also controls a stepper / servo motor that makes adjustments to the cup fill volume to compensate for out-of-spec weights. When downstream jams occur, the checkweigher controller passes cups back to the Solbern filler without recording weights. The checkweigher controller has an RS232 interface. The following functions should be available from the shop floor controller.

3.1.2.1 Production Line Control

Target Weights and Cutoffs: The production line controller shall be capable of downloading operational control data to the checkweigher controller. A download cycle shall be initiated by a computer communicating with the production line controller over data highway plus. Hereafter, this computer will be referred to as the "SCADA node". A download cycle shall consist of writing data to a set of registers of the production line controller. Data is then transferred over the RS232 port to the checkweigher. The contractor shall specify an appropriate handshake between the SCADA node and the production line PLC so that an acknowledgement is returned to the SCADA node when the operation is complete.

3.1.2.2 Data Logging

Weights: The checkweigher controller can transmit weights either individually or, on request, in blocks of size n. These options can be set in software. The production line controller should be able to set this function to either individual or block transmission. The production line controller should provide a set of registers to collect weight data and a corresponding set of registers to collect the time at which the weight was recorded and a corresponding bits that indicate the accept / reject zone in which the cup falls. A counter should provide the number of the last register beyond the base address that has been logged with a weight. The SCADA node will access weights by first enabling a bit that prevents new data logging from the checkweigher. The counter reading will then be taken. Starting from the base address, data will be read up to the current count. The cycle will end by resetting the counter and disabling the bit that inhibits data logging. The production line controller should be able to resume data logging at the weight sequentially following the last weight collected. The data logging will resume at the base addresses.

Count: The PLC shall maintain separate registers with the current count of filled cups that have been processed and the current count of filled cups that have been rejected. The total of these two registers indicate the total cups filled.

3.1.3 FEMC Filler. The FEMC filler provides continuous volumetric filling. The filling speed is controlled by a Danfoss variable speed drive and the cup height is controlled by an Electrocraft servo motor.

3.1.3.1 Production Line Control

Start / Stop: The FEMC filler should be started and stopped from the production line control panel. A return signal should be provided by the FEMC filler to indicate it is running.

Remote / Local operation: A remote / local switch should be provided so that the FEMC filler can be operated under local control. When operating under remote control, the start button on the FEMC controller is overridden by the start button on the production line control panel.

Control of cup height: Under remote control, cup height should be specified from the production line control panel. Adjustments via Electrocraft servo drive should be possible based on vegetable fill weight data as described in section 3.1.3.2.

3.1.3.2 Data Logging

Product Level: When the product level in the FEMC hopper is low alarm, a bit should be set in the production line controller.

Fault Condition: The production line controller should record the various failure conditions of the FEMC filler, including the motor drive failure.

Vegetable fill weights: FEMC fill weights are sampled and weighed on an off-line scale. This data shall be collected by the PLC and used to adjust FEMC cup height via servo control as described in section 3.1.3.1.

Temperature Sensor: The contractor shall install a non-contact temperature sensor above the main hopper for acquiring the vegetable temperature. Provision for logging the data will be made in the production line PLC.

Level Sensor: The contractor shall install an ultrasonic range sensor mounted above the FEMC main hopper. Provision for collecting the data shall be made in the production line PLC.

3.1.4 Product Feed Fillers. There are two bulk product feed fillers. One is servicing the Solbern filler and one is servicing the FEMC filler. In each case, low level sensors on the Solbern and FEMC detect the need for more material. The product feed fillers respond to a low level signal by conveying material into the Solbern or FEMC until a high level sensor is reached. At that point the conveyor is turned off until the low level sensor is encountered. This is a closed loop distributed control system and does not need to be integrated into the production line controller.

3.1.4.1 Production Line Control

Start / Stop: The product feed fillers should be started and stopped from the production line control panel. A return signal should be provided by the feed fillers to indicate they are on line.

3.1.4.2 Data Logging

Low product level: When the hoppers of the product feed fillers are low, a bit should be set in the production line controller. This will, in turn, turn on the low product pilot light. When material is brought from inventory and the hopper is replenished, this bit will be reset.

3.1.5 Oden Filler. The Oden filler consists of three rotary positive displacement pumps controlled by a digital controller encoder. There is no communication capability. Motion is controlled by a digital encoder coupled to a DC servo drive.

3.1.5.1 Production Line Control

On / Off Signal: When the Oden Filler is on, a return signal should be provided to the production line PLC to indicate it is on.

3.1.5.2 Data Logging

Temperature Sensor: The contractor shall install a non-contact temperature sensor for acquiring the gravy temperature. Provision for logging the data will be made in the production line PLC.

Level Sensor: An ultrasonic range sensor has been installed on the Oden filler. Gravy level data shall be logged by the production line PLC.

3.1.6 Tiromat Form-Fill-Seal Machine. The Tiromat is an intermittent motion form-fill-seal machine with four stations: Forming, Filling, Sealing, and Punching. The machine is controlled by an Allen Bradley PLC 2/17 controller that is programmed over RS232 using a proprietary software, the SMART system software. Once programmed, the PLC maintains functions within the control parameter setpoints. Under the configuration of Figure 1, programming of machine parameters shall be possible either from the SMART system or from the operator view node.

3.1.6.1 Production Line Control

Start / Stop: The Tiromat should be started and stopped from the production line control panel. A return signal should be provided by the Tiromat to indicate it is running.

Remote / Local operation: a remote / local switch should be provided so that the Tiromat can be operated under local control. When operating under remote control, the start button on the Tiromat is overridden by the start button on the production line control panel.

Program configuration and command bits: All program configuration and command bits currently programmed on the Tiromat controller should be capable of being programmed from the production line controller. A corresponding set of registers should be configured in the production line controller along with a software switch to download those registers to the Tiromat controller. A return signal from the Tiromat controller should indicate a successful data transfer. Setting registers in the production line controller and enabling the software switch for downloading will be done from the operator view node in the control panel via the SCADA node on Data Highway plus. Registers of the Tiromat controller are given in Appendix B.

3.1.6.2 Data Logging

Status bits / diagnostic bits / word assignments: All status and diagnostic bits, as well as measured data stored as integer or floating point variables, that exist in the Tiromat controller, should be duplicated in the production line controller. This data should be passed to the production line controller with the same frequency as currently exists when reporting data to the SMART system, which is approximately 1 Hz.

Production rate: A moving average of the production rate shall be calculated and stored in the production line controller. This calculation will be done every cycle and will be based on the previous five cycles.

Differential seal pressure: Two pressure transducers will be installed in the tiromat seal chamber, one on each side of the pouch film. Provision shall be made in the production

line controller for mapping the sensor data from the Tiromat controller during each operating cycle.

Seal plate temperature: Six temperature transducers will be installed on the seal plate of the Tiromat. Provision shall be made in the production line controller for mapping the sensor data from the Tiromat controller during each operating cycle.

Temperature Sensor: The contractor shall install a non-contact temperature sensor above the pouch just before the sealing operation.

3.1.7 Adept Pack-One Robot. The Adept robot, with drive and vision system, is controlled by a MC 68000 processor controller. RS 232 Serial ports are available for communication with the robot controller.

3.1.7.1 Production Line Control

Start / Stop: The robot subsystem should have start / stop control from the production line control panel. A return signal should be provided to indicate it is running.

Remote / Local Operation: A remote / local switch should be provided so that the robot subsystem can be operated under local control. When operating under remote control, the start button of the robot subsystem is overridden by the start button on the production line control panel.

3.1.7.2 Data Logging

Fault Conditions: All fault conditions should be sent to production line controller, where they are time stamped for data logging. Pilot light should go on when robot is the cause of error.

3.1.8 Videojet Printer. The Videojet printer has a serial communication port that allows a remote device to download text to be printed.

3.1.8.1 Production Control

Text transfer: The production line controller should be able to download text to be printed. Such text will be input to the production line controller from the control panel.

Remote operations: The operations of start, print, and head should be under the control of the production line controller.

3.1.8.2 Data Logging

Failure mode: Printer failure should be logged and time stamped. A pilot light should be provided to indicate printer failure.

3.1.9 Line Pressure and Vacuum

3.1.9.1 Production control

Pressure alarm settings: Provision should be made for mapping pressure and vacuum data from the Tiromat controller and setting alarm limits in the production line controller from the operator view node for line air pressure and line vacuum pressure.

3.1.9.2 Data Logging

Air supply pressure and vacuum supply pressure: Pressure transducers will be placed in the air supply line and the vacuum supply line. Provision shall be made in the production line controller to log the analog signals from these transducers. Alarm indicators are provided as in section 2.2.3.

3.1.10 Retort Rack Loader

3.1.10.1 Production Control

Start / Stop: The retort rack loader should be started and stopped from the production line controller. A return signal should be provided to indicate that it is running.

3.1.10.2 Data Logging

Fault conditions: The production line controller should record and time stamp fault conditions of the retort rack loader.

Counts: The production line controller should record the production counts for pouches loaded into the rack.

Cage Identification: The production line controller should take a bar code identification of the cage loaded into the retort rack and the time that the first pouch is loaded into the cage. The bar code scanner will be designed into the retort rack by Rutgers personnel.

Ancillary Equipment:

3.1.11 Radio Frequency Bar Code Transmitter / Receiver. For material tracking purposes, the production line controller should include a bar code scanner and radio frequency transmitter and receiver. Provision should be made in the controller for recording material lot numbers as material is loaded into filling equipment. Such information will be time stamped for tracking purposes.

3.1.12 Pouch Inspection Station. In order to track quality control problems, final pouch inspections will classify defects into 8 classes. Defective pouches will be inserted into a disposal chute based on defect type. Each chute will have a proximity sensor to record the passing of parts. The production line controller must keep count of the daily

counts passing each proximity sensor. The contractor shall make provision in the production line controller hardware and software for 8 digital inputs for this purpose.

4.0 Modes of Operation

This section contains a description of the required modes of operation of the control system. Each mode includes a description of the events or sequence of events that characterize that mode of operation.

4.1 Start Mode

- Check all machinery powered and ready.
- Product feeders on.
- Transfer pump on.
- Wait until product level OK: Solbern, FEMC, Oden.
- Dumper belt on.
- Checkweigher belt on.
- Wait until FEMC has cups (low level sensor activated).
- FEMC drive on.
- Solbern cycle start.
- Adept robot start.
- Robot conveyor start.
- Tiromat start.
- Retort loader and inspection conveyor on.
- Videojet head and printer on.

4.2 Stop Mode

- Tiromat stop.
- Wait until Tiromat cycle end.
- Feeders stop.
- FEMC drive stop.
- Solbern cycle stop.
- Checkweigher stop.
- Adept robot pause at end of cycle.
- Conveyors stop.
- Retort rack loader stop.
- Videojet head and print off.

4.3 Production Line Setup Mode

- Check power to all equipment.
- Load operating program parameters: Tiromat, Checkweigher, FEMC servo, Adept robot, Oden. Videojet printers.

4.4 Fault on Line Mode

Minor faults should be indicated on the control panel by change in color of the machine indicator.

Major faults should stop the line and be indicated on the control panel by change in color of the machine indicator. The following are major faults: a machine stops running, critical machine parameter out-of-tolerance per QC, filler out of product, dumper jam, retort loader jam.

4.5 Emergency Stop Mode

E-Stop all equipment: Tiromat, Solbern, FEMC, Adept robot, robot conveyor, Oden filler, product feeders, Transfer pump, retort rack loader, conveyors, checkweigher conveyor stop, Videojet head and print off.

4.6 Manual Operation Mode

Manual (local) operation of any machine can be selected at control panel.

While machine is set to manual, the line can be run automatically; however, any machine faults except E- will not stop the line.

5.0 Documentation Requirements

5.1 Software documentation shall be provided as follows:

1. The ladder logic diagram for the shop floor controller program.
2. A structured function chart that shows the modular design of the program.

5.2 Electrical drawings. Schematics shall be provided for all electrical wiring.

5.3 Layout drawings for control panel will be provided.

5.4 The contractor will supply manuals of operating procedures for all supplied equipment.

5.5 Contractor shall provide a spare parts list.

6.0 General

6.1 Cost. The proposal is to include total cost F.O.B. Rutgers University, CRAMTD building, 120 New England Avenue, Piscataway, NJ. Cost of optional equipment, recommended spare parts and accessories should be quoted but clearly delineated from the base bid.

6.2 Delivery Schedule. The vendor will specify engineering design, fabrication, testing and delivery schedule.

6.3 Service. The vendor will provide service as needed to fulfill requirements of the warranty and these specifications.

6.4 Award. The criteria for selecting a proposal will be based on the evaluation of the CRAMTD staff:

Delivery
Engineering features
Cost
Service
Training and support

6.5 Exceptions. The vendor is to clearly identify any exceptions taken from these specifications.

6.6 Warranty. The vendor warrants the equipment performance specified herein for one year from the date of acceptance.

7.0 Acceptance

Acceptance test. The equipment will be subject to an acceptance test to determine whether performance requirements have been met. The equipment will be tested for all functions as described herein.

8.0 Shipping and Installation

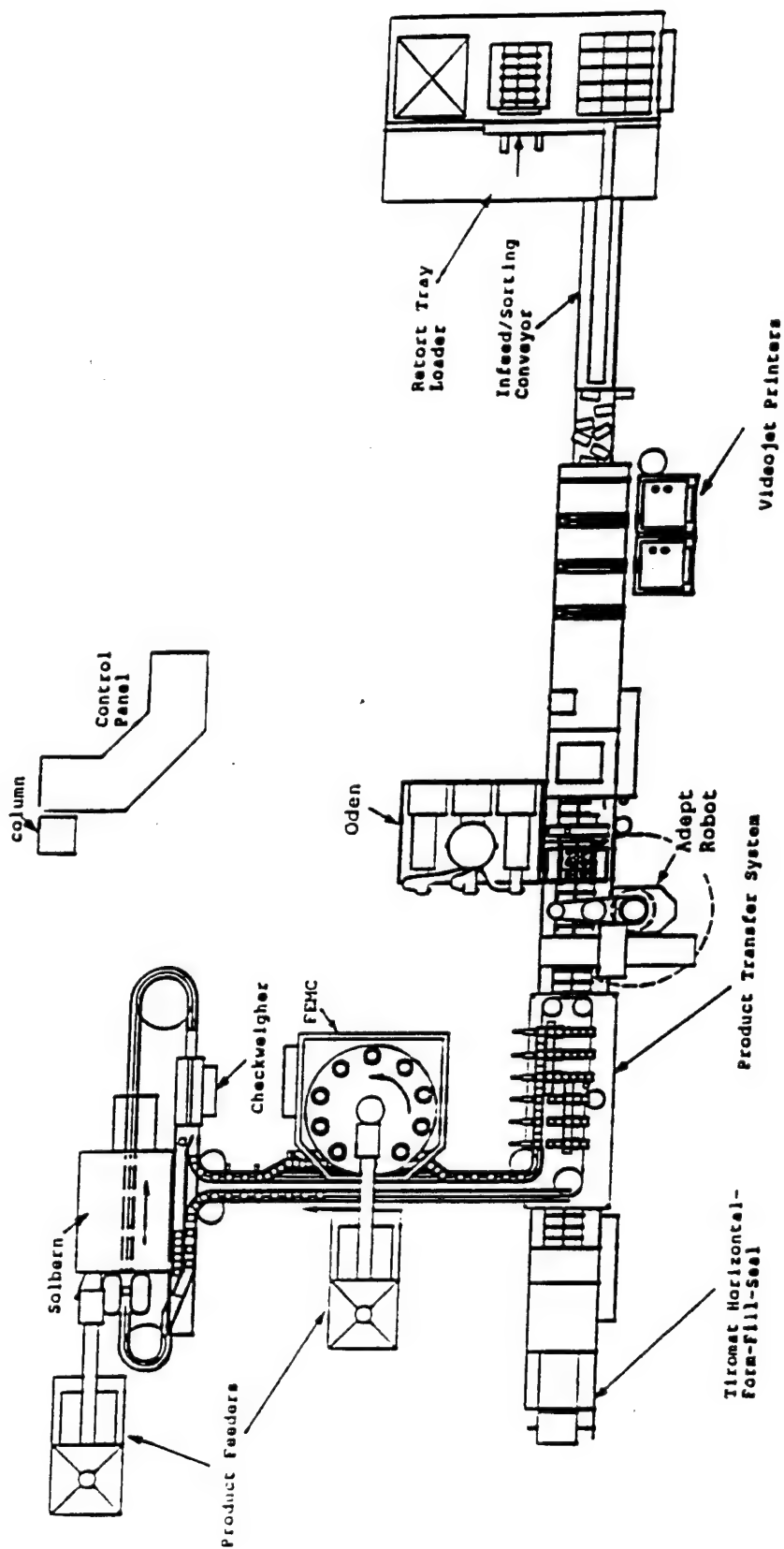
8.1 The equipment will be shipped F.O.B., Rutgers University, CRAMTD building, 120 New England Avenue, Piscataway, NJ.

8.2 The vendor will assemble and install equipment in full working order and mprovide training to Rutgers Personnel in the operation and maintenance of the equipment.

APPENDIX A

Computer Hardware Specification for the MRE Pouch Operator Interface Workstation

- 80486 DX2 66MHZ Processor
 - 16 mb RAM
 - 350 mb Hard Drive
 - 3.5", 1.4mb Floppy Drive
 - (2) Serial, (1) parallel Port
 - SVGA Graphics card with 1mb Memory
 - 19" SVGA Monitor
 - MS DOS, Version 6.x
 - Microsoft Windows for Workgroups 3.11
 - Ethernet Card: SMC Ethernet Plus Elite COMBO, 16 bit with 3 connectors:
 - AUI (thick ethernet, 10Base-5)
 - BNC (thin ethernet, 10Base-2)
 - RJ45 (twisted pair 10Base-T)
- Note: 3COM with same specifications also acceptable.
- Microsoft Mouse



MRE POUCH LINE

FIGURE 1

Control Panel for H-F-F-S Line

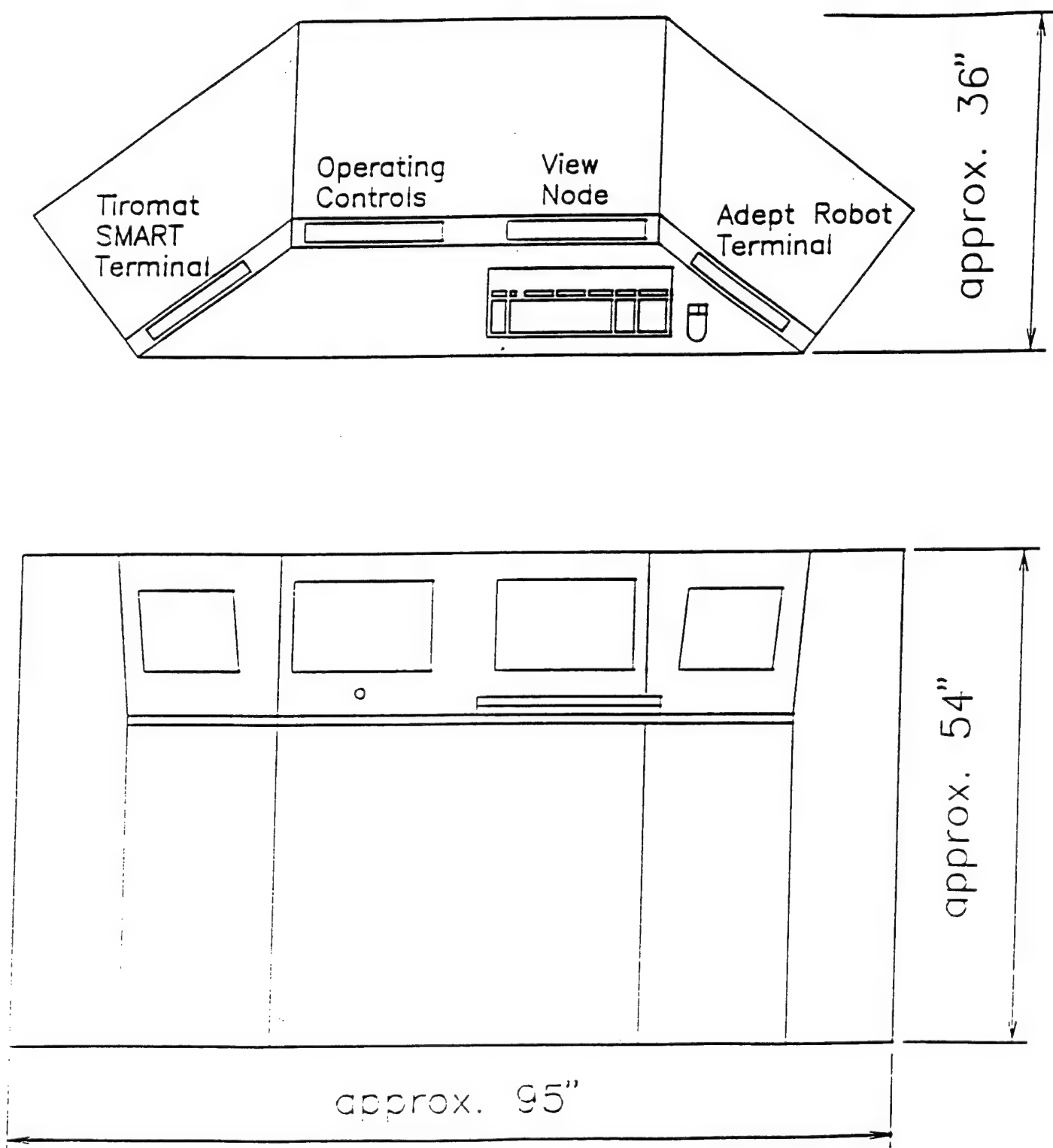


Figure 2

Integration of MRE Pouch Line

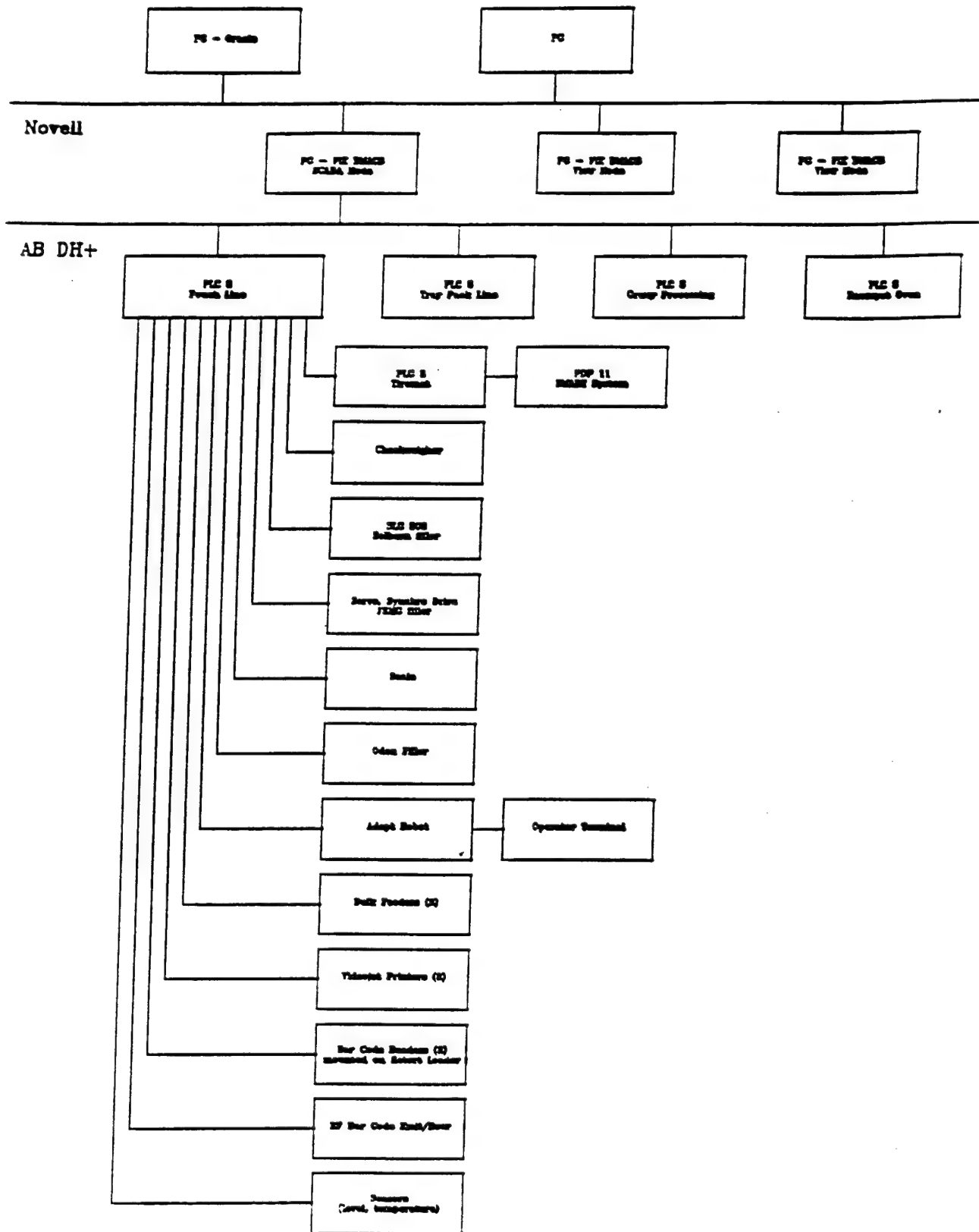


Figure 3

COMBAT RATION ADVANCED MANUFACTURING TECHNOLOGY DEMONSTRATION (CRAMTD)

Quality Assurance for Raw Material and Finished Goods: Database Design and Implementation

Technical Working Paper (TWP) 87

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MS/CIS Department
Faculty of Management**

August 1994

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1 Introduction

The Combat Rations Advanced Manufacturing Technology Demonstration (CRAMTD) project is sponsored by the United States Department of Defense DOD and the Defense Logistics Agency (DLA). The goals of the project are to create a pilot facility to demonstrate advanced manufacturing technologies which include computer integrated manufacturing (CIM). Quality assurance (QA) and process control are among the various functions to be supported by the CIM system.

The sample products under consideration for trial manufacturing are thermostabilized beef stew in an MRE pouch (MIL-P-44073B) and thermostabilized beef chunks and gravy in a tray pack (MIL-B-44230B). Each product contains materials such as beef and vegetables as well as a variety of additional ingredients. The quality control functions insure that only consistent goods are manufactured and released for consumption.

Quality control in the manufacturing environment can be broken down into three distinct phases: Raw material, In-Process and Finished goods. These phases mirror the chronological path of materials from the time of delivery, through production and finally to the time of shipment. In this paper we focus only on the quality control of raw material and finished goods. Quality control for work in-process will be addressed in a separate paper.

2 Definitions

The following definitions pertain to CRAMTD production database and the operations of the CRAMTD food production facility.

- **Batch** - A collection of sub-assemblies or finished products produced during a given time period.
- **Location** - A physical area within the plant or warehouse. Examples are Loading Dock, Quarantine, Freezer, etc.
- **Material Lot** - A collection of raw material or finished products as tracked internally by the production database.
- **Material Lot Number** - A unique identifier assigned by the production database at the time of delivery or at the time of creation.
- **Operation** - A stage in the production process where one or more raw materials or sub-assemblies are transformed into finished goods or sub-assemblies.
- **Organization** - Any enterprise involved with, or related to, the CRAMTD food production facility. These include vendors, suppliers, customers, etc.
- **Production Database** - The central plant database where all production, quality and materials management data reside.
- **Production Line** - A collection of machines used to convert raw materials into finished goods.

- **State** - The disposition of an entire material lot. Examples are "IN QC", "RELEASED" and "REJECTED".
- **Status** - An indication of the disposition of

3 Military Standards for Testing

The CRAMTD project adopts the Department of Defense sampling plans which are known as the Military Standard MIL-STD-105E: Sampling Procedures and Tables for Inspection by Attributes. This Standard is the basis for determining the frequency, sample sizes and many other parameters of the sampling and testing process. The Standard, which is also the basis for the latest ISO 9000 testing recommendations, is described (including all tables) in a document that was released in 1989. The standard is quite lengthy, includes many options and is flexible enough to support testing structures from the very simple, to the very complex.

The Military Standard for quality control testing, specifies:

1. When to test a material lot
2. How much material to take for testing
3. The criticality of defects
4. The number of defects sufficient to accept or reject the lot

3.1 Major Components of the Military Sampling Plan

The following are the major elements of the military sampling plan.

- **Acceptable Quality Level (AQL)** - An upper limit to the level of defects present in a material. An AQL of 0.10 would indicate that on average, a material should be have less than 0.10 defects per 100 units.
- **Code Letter** - A place holder determined by an inspection level and a lot size range.
- **Inspection levels** - A group of code letters with distributions that grow wider as the inspection levels grow more general. For example, the range of inspection level S-1 is [A..D] where the range for inspection level S-4 is [A..K].
- **Lab Procedure** - An outline describing some tasks to be performed in the lab using lab equipment. Several lab procedures may be used to complete one test procedure.
- **Material Specification** - A cross reference between a particular material and a particular test procedure indicating the AQL, sample unit size and frequency for testing.
- **Sample** - One or more units of a material selected from a batch or lot.
- **Sample Size** - The number of sample units contained in one sample.

- **Sample Unit** - A collection of material considered a sampleable unit.
- **Sample Unit Size** - The amount of a given material in one sample unit. This is usually given in the same units of measure the material is stored in.
- **Sampling Plan** - A plan for how often to sample a material. Two popular plans are Single Sampling where only one round of samples is taken and Double Sampling where two rounds may be performed depending on the outcome of the first round.
- **Strictness** - The rigidity of sampling for a particular supplier of a particular material. Strictness can shift between Normal, Reduced and Tightened depending on the quality of material a supplier is providing.
- **Test Procedure** - An individual test to be performed on a material. One or more lab procedures may be used.

4 Raw Materials Testing

The quality of raw materials is a major factor in the overall quality of a product. A large number of quality problems arising at the finished goods stage could be attributed to variations in the quality of the ingredients.

Raw material testing is triggered by the arrival of new material lots and acts as a gatekeeper by preventing defective materials from entering the manufacturing process. Materials which are ordered and delivered to the enterprise must be tested for conformance to standards before being used in production. These tests begin when a delivery is first attempted at the warehouse.

The first tests are of inspection nature and are, in most cases, administered by the receiving clerk at the warehouse. It is his/her responsibility to examine the delivery for any obvious defects.

If such defects are found, the delivery can be turned away with the enterprise taking no formal control or ownership over the materials.

This *initial* inspection includes information about accepted and turned away delivery attempts. This record of delivery attempts is used to support future purchasing decisions.

For example, the products made at the CRAMTD facility use raw and pre-cooked beef as a raw material. Beef is typically frozen and must be delivered in a refrigerator or freezer truck. Upon delivery, the temperature and conditions of the truck are examined. If, during shipping, the truck has malfunctioned and the beef has been allowed to thaw, the receiving clerk may reject the entire shipment.

In the event that the material lot passes the initial inspection, it is then formally accepted and the enterprise now owns and is responsible for the materials. Each received material lot is assigned a material lot number, which uniquely identifies that collection of material throughout its existence at the plant. The lot is assigned an initial state of "IN QC" (indicating that it has to undergo further testing by the quality control department) and all lot location are given an initial status of "ON HOLD". Lastly, the lot is placed in a Quarantine area of the warehouse. All relevant information about each material lot received is recorded in the database and the quality control department is notified of such lots.

For each received material lot, the quality control department determines if one or more samples need to be withdrawn and subjected to a series of tests before releasing the material to production.

This determination is made based on the military sampling plans and guidelines and/or the quality control policies of the plant. Again, for the CRAMTD food production facility, critical raw materials such as beef must undergo testing according to MIL-STD 105E standard as explained in the following section.

4.1 Military Sampling Plan for Raw Materials

Several tables defined by the standard are used to determine the number of samples to take and the number of defects sufficient to accept or reject a lot.

A portion of the first table, "Sample Size Code Letters" is presented below. The sample size is the number of material in a sample. Code letters from A to Q are used to designate relative sample sizes. Using the table below, the sample size code letter that corresponds to a given inspection level and a given lot size can be determined.

Lot/Sample Size	Special Inspection Levels				General Inspection Level		
	S-1	S-2	S-3	S-4	G-1	G-2	G-3
2 to 8	A	A	A	A	A	A	B
9 to 15	A	A	A	A	A	B	C
16 to 25	A	A	B	B	B	C	D
26 to 50	A	B	B	C	C	D	E
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

The Lot Size Range is given in "sample units". For example, if one wishes to test beef and we require 5 pounds of beef in order to perform all of our tests one time, a "sample unit size" of 5 pounds of beef would be defined and the received lot would be viewed as a multiple of the "sample units", e.g., a 100 pound lot of beef is viewed as a lot of size 20 "sample units" each is 5 pounds.

When the testing specification for a given material is defined, the Inspection Level at which the enterprise would like to test the material is supplied. For example, for raw beef, Special Inspection Level 2 or "S-2" for short, is indicated.

The Code Letter is used as a criterion for determining the sample size and the levels of defects considered for accepting or rejecting a lot. Other parameters include AQL (e.g., 10%), Strictness (Normal, Tightened, Reduced), Sampling Plan (Double or Single) and current Round if using Double or Multiple sampling plans. The Code Letter table is based on Raw Materials and Finished Goods material lots.

These tests are typically performed off-line in a quality control laboratory. The suite of raw material tests are required by the United States military for producing combat rations. Examples of such raw materials tests include:

- Beef - Foreign Odor/Color/Material
- Beef - Drain Weight Yield

- Beef - Surface Fat Thickness
- Beef - Microbial Count
- Beef - Size of Beef Chunks
- Tray Pack Can - Dents, Scratches and Rust

The tests results will determine if the material is suitable for its intended use. Lots that fail inspection are deemed rejected and may be either returned to the supplier, physically destroyed or re-tested to determine if they can be used for a less critical formulation. For example, a lot of grade A peas which fails to meet grade A specifications may be used in a formula where grade B peas is sufficient.

The results of these tests are also used to support future purchasing decisions.

5 Finished Goods Testing

All finished products are held for testing before being released to shipping. The finished goods tests are performed to confirm the safety of the product and to ensure compliance with military quality standards. As with raw materials, lots of finished product are sampled and tested in the quality control laboratory. Examples of such tests include:

- Incubation
- Gravy Consistency
- Excessive Heating
- Drain Weight of Beef
- Tears, Cuts, Holes in Pouch Material (MRE Pouch)
- Pouch Seal Width and Condition (MRE Pouch)

For thermostabilized products, the incubation test provides a critical safety check and also reflects on the effectiveness of the sterilization process. Other tests verify the product is within military standards.

For Finished products, there are different schedules prescribed in various military standards. For example, the Beef Chunks with Gravy, Thermostabilized, Tray Pack (MIL-B-44230B) has the Sample Size and Acceptance criteria combined in one table. The double sampling plan prescribed by the standard is as follows:

Finished Product Lot Size	Sample Size	Cumulative Sample	Accept Level	Reject Level
0 to 3200	8	-	0	2
	8	16	1	2
3200 to 35000	13	-	0	3
	13	26	3	4

It is important to note that, aside from the differences in the finished product sampling schedules, the procedures for sampling, testing and accepting or rejecting a lot of finished goods is identical to the raw materials case.

6 Database Design

The information systems of an organization is made up of a set of activities that regulates the sharing and distribution of information and the storage of data that are of relevance to the operation and management of the organization.

A proper design of the underlying database of an information system of an organization must therefore be based on the understanding of the system's activities and their information requirements. Below is a discussion of our model of the system's activities followed by a discussion of the corresponding data model.

6.1 The Functional Model

The functional analysis has been performed by a top-down, structured, systems analysis technique called IDEF0 [5, 6, 7]. The IDEF0 model of the CRAMTD application is described in [2]. The IDEF0 technique models a system's activities and the information flow among them. To construct an IDEF0 model, we initially represent the generic activities of the system and then successively decompose each of these activities into greater details. The building blocks of the IDEF0 model are:

- The activity (function) box: This represents an activity or function of a system. This could be either a generic activity or one of the detailed activities that constitute a generic activity.
- Arcs: These represent inflow and outflow associated with a given function box. There are four types of arcs:
 - Input: Represents the set of inputs, e.g., information and materials required to perform the activity. This is depicted by an arrow entering the activity box from the left.
 - Output: Represents the outflow from the activity. This is depicted by an arrow leaving the activity box from the right
 - Control: Represents the constraints that govern the process by which the activity is performed. This is depicted by an arrow entering the activity box from the top.
 - Mechanism: Represents the human or equipment resources that are required in performing the activity. This is depicted by an arrow entering the activity box from the bottom.

More than 100 activities are identified in the target application area. For more details about the functional model of the CRAMTD application see [2].

6.2 The Data Model

The technique used for data modeling is known as IDEF1X, a semantic data model based on Codd's relational data model [4] and Chen's entity-relationship model [3]. An entity is an element of the system that is relevant to the QA operation. An entity could be something tangible such as a receiving clerk or something more abstract such as an inspection procedure. Each entity is described in terms of one or more attributes. The real life interaction between one entity and another is represented in the E-R model by a relationship. A diagram of these entities and their relationships is known as an E-R diagram. The IDEF1 model is used to develop the conceptual schema of the application. The building blocks of the IDEF1X model are entities, attributes, and relationships. The IDEF1X model for our target application is described in more detail in [1].

Entities are represented by boxes in the IDEF1X model. Identifier-dependent (ID) entities, which are child entities whose existence depends on that of the parent entity, are shown by boxes with round corners. Identifier-independent (II) entities have independent existence, and are shown with boxes with square corners.

Attributes of an entity are listed inside the entity box. The primary key attributes are listed above a horizontal line inside the entity box. ID entities *inherit* the primary key attributes of their parent entities. Multiple inheritance is allowed in this data model.

Relationships are represented by arcs in the IDEF1X model. If one of the entities connected by an arc is child entity, then the arc is represented by a bold line. The dot at the end of an arc identifies the child entity. Arcs connecting two entities that do not have a parent-child relationship are represented by a dashed line. Relationships are named by verb phrases. In addition, a fully developed IDEF1X model replaces each m:n relationship with an additional cross reference entity and two 1:n relationships.

6.3 The CASE Model

Using Oracle Computer Aided Software Engineering (CASE) tools, specifically Oracle CASE*Dictionary and Oracle CASE*Designer, the user requirements and the Military Standard were translated into a single function hierarchy that shows all the relevant activities. The IDEF0 model introduced in the previous section was used as a starting point to develop a functional hierarchy that is integrated with the E-R model.

In a functional hierarchy, the higher level, generalized functions are at the top and more detailed functions are shown at the bottom (see Appendix I). The leaf nodes in the hierarchy are elementary functions that may become actual data entry or reporting screens.

Each of these activities are further defined, based on the entity relationship model (E-R), in terms of the entities, attributes, and the relationships they use. The QA application requires the use of over 25 elementary functions. Some of these are described in the *Function to Entity Matrix* report shown in Appendix II. An example matrix for the *AQL Data Entry* function is given below.

- **Function : Q0.1**

Definition: AQL Data Entry

Entity	Create	Retrieve	Update	Delete
-----	-----	-----	-----	-----
ACCEPTABLE QUALITY LEVEL	Y	Y	Y	Y

The model defined in the Oracle CASE tool reflects the rules of the business as described by the personnel at the CRAMTD food production facility. The business rules can be captured as relationships between entities, additional attributes for an entity or the use of an entity by a particular function. The Oracle CASE*Designer provides an E-R diagramming function as shown in Appendix III.

Entities and their definitions can be seen in the *Entity Definition Report* provided by CASE*Dictionary. A full *Entity Definition* report for the QA application is shown in Appendix IV. As an example, the definition for the AQL entity is shown below.

- **ACCEPTABLE QUALITY LEVEL**

The quality level associated with a given material. Determines the levels of defects tolerated.

Entities are related to one another by relationships. The Oracle CASE tools allow the designers and analysts to designate meaningful sentences for each relationship that reflects the *business rules* of the enterprise.

Each relationship has two participating entities at each end. The entities are designated by their names as shown in the previous figure. The participation in the relationship can be either *mandatory* or *optional* and is indicated by the phrases "MUST BE" and "MAY BE" respectively. Relationships also have cardinality as expressed by the phrases "ONE AND ONLY ONE" and "ONE OR MORE".

The following relationships are used to link the entities of the Quality Control application:

- each acceptable quality level may be the AQL specified in one or more material test specifications
- each acceptable quality level may be the AQL used in one or more sampling plan lookup tables
- each area material restricted must be material restrictions to one and only one area type
- each area material restricted must be a restriction of an area type to one and only one material
- each area type may be a description for the type of one or more warehouse areas
- each area type may be a restricted type of area in one or more area materials restricted

- each code letter may be the code letter in one or more inspection level code letters
- each code letter must be a code letter used in one or more sampling plan lookup tables
- each inspection level code letter must be a code letter from one and only one code letter
- each inspection level code letter must be a code letter identified by one and only one lot size
- each inspection level code letter must be a code letter determined by one and only one inspection level
- each inspection level may be the level specified in one or more material test specifications
- each inspection level may be a test letter based on one or more inspection level code letters
- each inspector may be responsible for inspecting one or more material test results
- each inventory sample must be an instance of sampling from one and only one material lot location
- each lab procedure detail may be referenced by one or more procedure cross references
- each lot comment must be made by one and only one person
- each lot comment must be a user comment concerning one and only one material lot
- each lot size may be a range of sizes used to determine one or more inspection level code letters
- each lot size must be a lot size range for materials of one and only one material type
- each material audit trail must be a transaction of one and only one material transaction type
- each material audit trail must be a record of changes to one and only one material lot location
- each material audit trail must be an action performed by one and only one person
- each material lot location may be changing status in one or more material status logs
- each material lot location must be classified under one and only one material status
- each material lot location may be changed and recorded by one or more material audit trails
- each material lot location must be associated with one and only one material lot
- each material lot location may be sampled in one or more inventory samples

- each material lot location must be a location described by one and only one warehouse bin location
- each material lot may be placed in one or more material lot locations
- each material lot may be changing state as recorded in one or more material state logs
- each material lot may be supplied by one and only one organization
- each material lot may be the subject of one or more lot comments
- each material lot must be made up of one and only one material
- each material may be a material referenced by one or more organization materials
- each material may be associated with one or more material lots
- each material may be related to one or more material type cross references
- each material may be tested according to one or more material test specifications
- each material may be cross referenced to a warehouse in one or more material warehouses
- each material may be restricted to one or more area materials restricted
- each material state log must be a record of changes of one and only one material state
- each material state log must be created by one and only one person
- each material state log must be a record of state changes for one and only one material lot
- each material state may be a state in one or more material state logs
- each material status log must be changed by one and only one person
- each material status log must be a record of status changes for one and only one material lot location
- each material status may be the status of one or more material lot locations
- each material test result must be the results from one and only one sample instance
- each material test result must be recorded by one and only one person
- each material test result must be performed by one and only one inspector
- each material test result must be a result of one and only one test attribute specification
- each material test specification must be a testing specification for one and only one material

- each material test specification must be a testing specification using one and only one sample rule
- each material test specification must be a specification with one and only one acceptable quality level
- each material test specification must be a specification for one and only one test procedure
- each material test specification must be a specification with one and only one inspection level
- each material transaction type may be the transaction type for one or more material audit trails
- each material type cross reference must be a material type cross reference of one and only one material type
- each material type cross reference must be a material cross reference of one and only one material
- each material type may be is related to one or more material type cross references
- each material type may be the material type used for one or more lot sizes
- each material warehouse (derived) must be a record of a warehouse storing one and only one material
- each material warehouse (derived) must be a cross reference of material stored one and only one warehouse
- each organization material history must be a recording of events concerning one and only one organization material
- each organization material may be a relationship with events recorded in one or more organization material histories
- each organization material must be a material reference for one and only one material
- each organization material must be an organization reference for one and only one organization
- each organization may be the supplier of one or more material lots
- each person may be responsible for recording one or more material test results
- each person may be the author of one or more lot comments
- each person may be responsible for materials changes in one or more material audit trails
- each person may be responsible for creating one or more material state logs

- each person may be responsible for creating one or more material status logs
- each procedure cross reference must be the inspection procedure reference for one and only one test procedure
- each procedure cross reference must be the lab procedure reference for one and only one lab procedure detail
- each sample instance may be resulting in one or more material test results
- each sample instance must be an instance with parameters from one and only one sampling plan lookup table
- each sample rule detail may be implemented in one or more sampling plan lookup tables
- each sample rule detail must be a series of sampling rounds recorded in one and only one sample rule
- each sample rule may be a description of a sampling round for one or more sample rule details
- each sample rule may be the plan used in one or more material test specifications
- each sampling plan lookup table may be used to supply parameters to one or more sample instances
- each sampling plan lookup table must be a plan tested under one and only one acceptable quality level
- each sampling plan lookup table must be an entry based on one and only one code letter
- each sampling plan lookup table must be an implementation of one and only one sample rule detail
- each sampling plan lookup table must be a plan at one and only one strictness
- each strictness may be used in one or more sampling plan lookup tables
- each strictness may be imposed upon one or more organization material histories
- each test attribute specification may be an attribute recorded in one or more material test results
- each test attribute specification must be the detailed specification for one and only one test procedure
- each test procedure may be cross referenced by one or more procedure cross references
- each test procedure may be detailed in one or more test attribute specifications

- each test procedure must be the test for one or more material test specifications
- each warehouse area may be composed of one or more warehouse bin locations
- each warehouse area must be in one and only one warehouse
- each warehouse area must be classified by one and only one area type
- each warehouse bin location must be in one and only one warehouse area
- each warehouse bin location may be the location of one or more material lot locations
- each warehouse may be divided into one or more warehouse areas
- each warehouse may be storing material referenced by one or more material warehouses

7 Database Implementation

The implementation of the quality control portion was done using a third Oracle product: the CASE*Generator. This tool takes the function to entity matrix and constructs data entry forms and reports that are bound together by menus. In general, the CASE*Generator can handle complex user requirements and business rules. In our case, however, due to the complexity of the Military Standard we had to include additional customized code to the generated forms.

To standardize the custom coding process, a code review was performed to identify common sections of code that could be generalized and shared between several data entry screens. Such code can be placed into "Packaged Procedures" and automatically included in each form via the CASE*Generator.

The final system is implemented on a local area network using a combination file and database server serving a client machine in the quality control lab. The two computers are connected over the building-wide ethernet network using the Novell Netware IPX/SPX protocol. The server runs Oracle Database Server for Netware and the client machine runs the Oracle tools suite; SQL*Forms, SQL*ReportWriter, SQL*Menu and SQL*Plus.

8 Quality Assurance Database Menu Options

Quality control lab technicians will be presented with a pull-down menu. The menu items and the associated submenus are shown in Figures 1 through 8.

9 Quality Assurance Database Screens

The database screens for the QA module are shown in Figures 9 through 28.

```
Materials  Quality  Production  Purchasing  Distribution  Maintenance  Exit
----- CRAMTD -----
```

Figure 1: The Main Menu of the CRAMTD Application

```
Materials  Quality  Production  Purchasing  Distribution  Maintenance  Exit
-----+-----+ CRAMTD -----
      | Reference Data > |
      | Test Setup      > |
      | Testing         > |
      | Vendor Eval.    > |
      | Inquiry         > |
      | Reporting       > |
      +-----+
```

Figure 2: The Quality Assurance Menu

Materials	Quality	Production	Purchasing	Distribution	Maintenance	Exit
-----+-----+-----+-----						
		Reference Data >		AQL		
		Test Setup >		Lot Sizes		
		Testing >		Insp. Level		
		Vendor Eval. >		Code Letter		
		Inquiry >		Strictness		
		Reporting >		Sample Rules		
	+-----+-----			Ins. Lev. Lettr		
				Samp Plan Table		
			+-----+-----+			

Figure 3: Quality Assurance - Reference Data Submenu

Materials	Quality	Production	Purchasing	Distribution	Maintenance	Exit
-----+-----+-----+-----						
			CRAMTD			
		Reference Data >	+-----+-----+			
		Test Setup >		Test Procedures		
		Testing >		Test Proc Attr.		
		Vendor Eval. >		Lab Procedures		
		Inquiry >		Associate Procs		
		Reporting >		Mat. Test Spec.		
	+-----+-----					

Figure 4: Quality Assurance - Test Setup Submenu

Materials	Quality	Production	Purchasing	Distribution	Maintenance	Exit
-----+-----+----- CRAMTD -----						
		Reference Data	>			
		Test Setup	>		+-----+-----	
		Testing	>		Review Lots	
		Vendor Eval.	>		Det. Procedures	
		Inquiry	>		Rec. Results	
		Reporting	>		Review Results	
+-----+-----+-----						

Figure 5: Quality Assurance - Testing Submenu

Materials	Quality	Production	Purchasing	Distribution	Maintenance	Exit
-----+-----+----- CRAMTD -----						
		Reference Data	>			
		Test Setup	>			
		Testing	>		+-----+-----	
		Vendor Eval.	>		Org. Mat. Data	
		Inquiry	>		Org. Mat. Hist.	
		Reporting	>		Org. Lots	
	+-----+-----				Lot Defect Rep.	
+-----+-----+-----						

Figure 6: Quality Assurance - Vendor Evaluation Submenu

Materials	Quality	Production	Purchasing	Distribution	Maintenance	Exit
-----+-----+----- CRAMTD -----						
		Reference Data	>			
		Test Setup	>			
		Testing	>			
		Vendor Eval.	>	+-----+-----		
		Inquiry	>		Review QA Res.	
		Reporting	>		QA Result. Page	
	+-----+-----				Detailed Result	
				+-----+-----		

Figure 7: Quality Assurance - Inquiry Submenu

Materials	Quality	Production	Purchasing	Distribution	Maintenance	Exit
-----+-----+----- CRAMTD -----						
		Reference Data	>			
		Test Setup	>			
		Testing	>			
		Vendor Eval.	>			
		Inquiry	>	+-----+-----		
		Reporting	>		Lots In QC	
	+-----+-----				Lots Rejected	
					Vendor Lots	
					Vendor Lot Def.	
					Bulk Test Rest.	
					Defects - By TP	
					Defects - By IS	
				+-----+-----		

Figure 8: Quality Assurance - Reporting Submenu

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Date 28-JUN-94

A decimal number indicating the AQL.

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User OPS\$USER

Lot Size Range Data Entry

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Date 28-JUN-94

-AQ-

+-- Material Types -----+			
	Material	Material Type	
	Type Id: RAW	Description: RAW MATERIAL	
+-- Lot Sizes -----+			
	Range Id	Lot Size Low	Lot Size High
	1	0	8
	2	9	15
	3	16	25
	4	26	50
	5	51	90
	6	91	150
	7	151	280
	8	281	500
	9	501	1200
+-----+			

A short unique identifier for the material type.

Figure 10: Quality Assurance | Reference Data | Lot Size Data Entry Screen

User OPS\$USER

Inspection Level Data Entry

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```
+-- Inspection Levels -----+
|
| Level Id   Description
| S1        Special Inspection Level 1
| S2        Special Inspection Level 2 (Used the most)
| S3        Special Inspection Level 3
| S4        Special Inspection Level 4
| S5        Special Inspection Level 5
| G1        General Inspection Level 1
| G2        General Inspection Level 2
| G3        General Inspection Level 3
|
|
|
+-----+

The unique inspection level id. S1, S2,...S5, G1, G2 or G3
```

Figure 11: Quality Assurance | Reference Data | Inspection Level Data Entry Screen

-AQ-

The unique identifier for the sampling plan.

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The unique strictness.

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User OPS\$USER Inspection Level Code Letter Data Entry Page 1 of 1
 Date 28-JUN-94
 -AQ-

+-- Material Types -----				
Material		Material Type		
Type Id: RAW		Description: RAW MATERIAL		
+-- Inspection Level Code Letters -----				
Low		High	Level Id	Code Letter
0		8	S2	A
9		15	S2	A
16		25	S2	A
26		50	S2	B
51		90	S2	B
91		150	S2	B
151		280	S2	C
281		500	S2	C
+-----				

A short unique identifier for the material type.

Figure 14: Quality Assurance | Reference Data | Inspection Level Code Letter Data Entry Screen

+-- Material Types -----+	
Material	Material Type
Type Id: RAW	Description: RAW MATERIAL
+-- Sample Rules -----+	
Rule Id: DOUBLE	Description: Double Sampling plan
+-- Strictness -----+	
Strictness: NORMAL	Description: Normal
+-- Sampling Plan Lookup Tables -----+	
+-----+	

A short unique identifier for the material type.

Figure 15: Quality Assurance | Reference Data | Sampling Plan Lookup Table - (Page 1)

User OPS\$USER

Sampling Plan Lookup Tables

Page 2 of 2
Date 28-JUN-94

+-- Material Types -----+						
+-- Sample Rules ----- Strictness -----+						
Rule Id: DOUBLE Strictness: NORMAL						
+-- Sampling Plan Lookup Tables -----+						
Code Letter AQL Round Sample Size Acc. Level Rej. Level						
B 4 1 2 0 1						
B 4 2 2 0 1						
C 4 1 3 0 1						
C 4 2 3 0 1						
D 4 1 5 0 2						
D 4 2 5 1 2						
E 4 1 8 0 2						
E 4 2 8 1 2						
F 4 1 13 0 3						
F 4 2 13 3 4						
+-----+						

The unique code letter.

Figure 16: Quality Assurance | Reference Data | Sampling Plan Lookup Table - (Page 2)

+--- Test Procedures -----+				
Test Proc.	Test Description	Attr	Freq.	Unit
RMT100100A	Vendor Evaluation	2	1	MONTH
RMT110100A	Vehicle Condition (frozen food)	3	1	DELIVERY
RMT111100A	Vehicle Condition (frozen, non food)	3	1	DELIVERY
RMT112100A	Vehicle Condition (refrigerated, food)	3	1	DELIVERY
RMT113100A	Vehicle Condition (refrig, non food)	3	1	DELIVERY
RMT114100A	Vehicle Condition (ambient, food)	2	1	DELIVERY
RMT115100A	Vehicle Condition (ambient, non food)	2	1	DELIVERY
RMT120100A	Certification	2	1	DELIVERY
RMT140100A	Foreign Odor/Color/Material	4	1	DELIVERY
RMT150100A	Microbial Count Beef	4	1	DELIVERY
RMT205100A	Beef Cook Yield (precooked beef)	4	1	DELIVERY
RMT205110A	Beef Texture (precooked beef)	2	1	DELIVERY
RMT205120A	Beef Cube Size (5/8" cube, precooked)	5	1	DELIVERY
RMT205130A	Beef Total Fat (precooked)	4	1	DELIVERY

The Unique identifier of an inspection procedure.

Figure 17: Quality Assurance | Test Setup | Test Procedure Data Entry Screen

User OPS\$USER Test Attribute Specification Data Entry Page 1 of 1
 Date 08-JUN-94
 -AQ-

+-- Test Procedures -----+				
	Test Proc. Id: RMT150100A			
	Description: Microbial Count Beef			Attr.: 4
+-- Test Attribute Specifications -----+				
	Attr. Num.	Attribute Name	Low Range	High Range
	1	Colony Count		
	2	Dillution Factor		
	3	Microbial Load		500000
	4	Defect	0	1
+-----+				

The Unique identifier of an inspection procedure - list of values available

Figure 18: Quality Assurance | Test Setup | Test Attribute Specifications Data Entry

User OPS\$USER

Review Material Test Specifications

Page 1 of 1

Date 08-JUN-94

-AQ-

```
+-- Materials -----+
|                                     |
|      Type 1      Type 2      Type 3      Type 4 |
| Material Id: 1    RAW        BEEF        CUBED  |
|                                     |
|      Desc.: Reformed Beef Cubes 5/8"           |
|                                     |
+-- Material Test Specifications -----+
|                                     |
| Seq.: 1    Test Proc.: RMT140100A Desc.: Foreign Odor/Color/Material |
|                                     |
| Attributes: 4      Test Freq.: 1      Test Freq. Units: DELIVERY |
|                                     |
| Frequency: 1      Sample Unit: 5      Unit UOM: LB. |
|                                     |
| Invocation: UPON ARRIVAL OR CREATION      AQL: 4 |
|                                     |
| Level Id: S3      Rule Id: DOUBLE |
|                                     |
+-----+
```

A unique identifier of a material.

Figure 19: Quality Assurance | Test Setup | Material Test Specifications

User OPS\$USER

Material Lots Requiring QC Inspection

Page 1 of 2

Date 08-JUN-94

-AQ-

+- Material Lots -----+-----+										
Lot	Create	Create	Material		Sample Info.					
Number	Date/Time	Quantity	UOM	Description	Cert.	Req.	Units			
63	16-NOV-93 12:11	500	LB.	Reformed Beef	N	3	X 5	LB.		
60	15-NOV-93 12:11	500	LB.	Reformed Beef	N	3	X 5	LB.		
64	17-NOV-93 12:11	200	LB.	Precooked Dice	N	2	X 5	LB.		
65	17-NOV-93 12:11	500	LB.	Reformed Beef	N	3	X 5	LB.		
67	17-NOV-93 12:11	500	LB.	Reformed Beef	N	3	X 5	LB.		
+--- Material Lot Locations -----+-----+										
Wareho Id	Area Id	Aisle	Tier	Bin	Status	Quantity	Withd	Units		
1	FREZ	1	1	4	ON HOLD	500	3	X 5	LB.	
								X		
								X		
								X		
								X		
+- Inventory Samples - Press Commit to Confirm Withdraw Round: 1										
-----+-----+										

Enter the Number of individual Samples to withdraw from this location.

Figure 20: Quality Assurance | Testing | Review Lots Requiring QC Inspection

User OPS\$USER

Record Inspection Results

Page 1 of 2

Date 08-JUN-94

-AQ-

```
+--- Inventory Samples -----+
|
| Samp. Id: 25      Sample Num.: 1    Lot Num.: 63    Mat.Id: 1    |
|
| Mat. Desc.: Reformed Beef Cubes 5/8"  Type: RAW    AQL: 4    Round: 1 |
|
+--- Material Test Specifications -----+
|
| Sequence  Test Procedure Description                                Attr |
| 1          RMT140100A  Foreign Odor/Color/Material                4    |
| 2          RMT210100A  Beef Cook Yield (reformed)                 4    |
| 3          RMT210110A  Beef Texture (reformed)                    2    |
| 4          RMT210120A  Beef Cube Size (5/8" cube, reformed)       5    |
| 5          RMT210130A  Reformed Beef Total Fat                    4    |
| 6          RMT210140A  Reformed Beef Connective Tissue            4    |
| 7          RMT210150A  Beef Bone Pieces (reformed)                5    |
|
+--- Material Test Results -----+
+-----+
A unique Id for the sample instance.
```

Figure 21: Quality Assurance | Testing | Record Inspection Results (Page 1)

User OPS\$USER

Record Inspection Results

Page 2 of 2
Date 08-JUN-94

```
+-- Inventory Samples -----+
|
| Sample          Sample          Material
| Id: 25          Num.: 1         Type: RAW          AQL: 4      Round: 1
|
+-- Material Test Specifications -----+
|
| Test: RMT140100A Foreign Odor/Color/Material          Attr.: 4
|
+-- Material Test Results -----+
|
| Inspector Id    Person Id    Attribute          Test Result
| 1              1            1 Foreign Odor          0
| 1              1            2 Foreign Color          0
| 1              1            3 Foreign Material        0
| 1              1            4 Defect                  0
|
|
|
+-----+
```

The unique identifier for the Inspector. - list of values available

Figure 22: Quality Assurance | Testing | Record Inspection Results (Page 2)

User OPS\$USER

Review QA Results

Page 1 of 2
Date 08-JUN-94
-AQ-

+-- Material Lots -----					
Lot Number	Material Id	Material Name		Mat. Type	
63	1	Reformed Beef Cubes 5/8"		RAW	
Org Id.	Organization Name	Create Date		Create Qty.	
3	Herman Alpert Co., I	16-NOV-93 12:11		500	
Curr. State	Last Changed	Qty. On Hand	Qty. In QC	Qty. Rej.	
IN QC	16-NOV-93	0	485		
+-- Organization Materials -----					
Organ. Id	Lots Acc.	Lots Rej.	Strictness	Last Changed	
3	4	4	NORMAL	07-JUN-94 12:06	
+-- Material Test Specifications -----					

A unique identifier of a material.

Figure 23: Quality Assurance | Testing | Review QA Results (Page 1)

User OPS\$USER

Review QA Results

Page 2 of 2
Date 08-JUN-94

+-- Material Lots -----+						
Lot Number: 63 Material: 1 Reformed Beef Cubes 5/8"						
+-- Sample Rounds -----+						
Round Required - Samples - Taken Recommendation						
1 3 3 ACCEPT this lot.						
2 3 0						
+-- Material Test Specifications -----+						

Figure 24: Quality Assurance | Testing | Review QA Results (Page 2)

User OPS\$USER

Organization Material Data Entry

Page 1 of 1
Date 31-JUL-94
-AQ-

+-- Organization Materials -----					
Material Id: 6		Descr.: Precooked Diced IQF Beef 5/8"			
Ordering UOM: LB.		Type: RAW	BEEF	DICED	
Org. Id: 3		Herman Alpert Co., Inc.		Priority: 1	
Lots Accepted: 3		Lots Rejected: 4		Total Lots: 7	
+-- Organization Material History -----					
		Current			
Transaction Date		Last Price	Strictness	Approval	Certificate
07-JUN-94 12:00		3	NORMAL	Y	N

A unique identifier of a material.

Figure 25: Quality Assurance | Vendor Evaluation | Organization Material Data Entry

User OPS\$USER

Lots Supplied by an Organization

Page 1 of 1
Date 31-JUL-94

-AQ-

```
+--- Organization Materials -----+
|
| Mat. Id: 6           Descr.: Precooked Diced IQF   Type: RAW   BEEF DICED
|
| Org. Id: 3           Name: Herman Alpert Co., Inc.
|
| Status: ACTIVE       Lots Acc.: 1                 Lots Rej.: 1
|
+--- Material Lots -----+
|
| Lot Num. Mat. State Last Changed Create Date Time Quantity Vendor Lot
| 44      RELEASED   21-FEB-94   17-FEB-94 12:00   800      VL13-FEB-94
| 66      REJECTED   13-JUN-94   10-JUN-94 01:44   700      VL04-JUN-94
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User OPS\$USER

Review A Full Page Of Qa Results

Page 1 of 1
Date 31-JUL-94
-AQ-

```
+-- Material Lots -----+
|
| Ingredient:  Precooked Diced IQF Vendor Name:  3   Herman Alpert Co.
| Date Rec.:   21-MAY-94 12:22      Vendor Lot #: VL18-MAY-94
|
|                               Strictness:  NORMAL
| Date Tested: 22-MAY-94          CRAMTD Lot #: 112          IN QC
| QC Tech.:   4  q.c. tech        Material Id:  6          RAW  BEEF
|
|                               Create Qty:  900
+-----+
| Test Procedure                               | Sampling Plan | Samp. Defects | |
| RMT140100A   Foreign Odor/Color/Materi | S3 DOUBLE    | 4.00 | 0    0    |
| RMT205100A   Beef Cook Yield (precooke | S3 DOUBLE    | 4.00 | 0    0    |
| RMT205110A   Beef Texture (precooked b | S3 DOUBLE    | 4.00 | 0    0    |
| RMT205120A   Beef Cube Size (5/8" cube | S3 DOUBLE    | 4.00 | 0    0    |
| RMT205130A   Beef Total Fat (precooked | S3 DOUBLE    | 4.00 | 0    0    |
| RMT205140A   Beef Connective Tissue (p | S3 DOUBLE    | 4.00 | 0    0    |
| RMT205150A   Beef Bone Pieces (precook | S3 DOUBLE    | 4.00 | 0    0    |
| RMT150100A   Microbial Count Beef      | S3 DOUBLE    | 4.00 | 0    0    |
+-----+
A unique identifier used by CRAMTD.  Press [List] for Lot Comments.
```

Figure 27: Quality Assurance | Inquiry | QA Result Page

User OPS\$USER

Lot Defects by Test Procedure

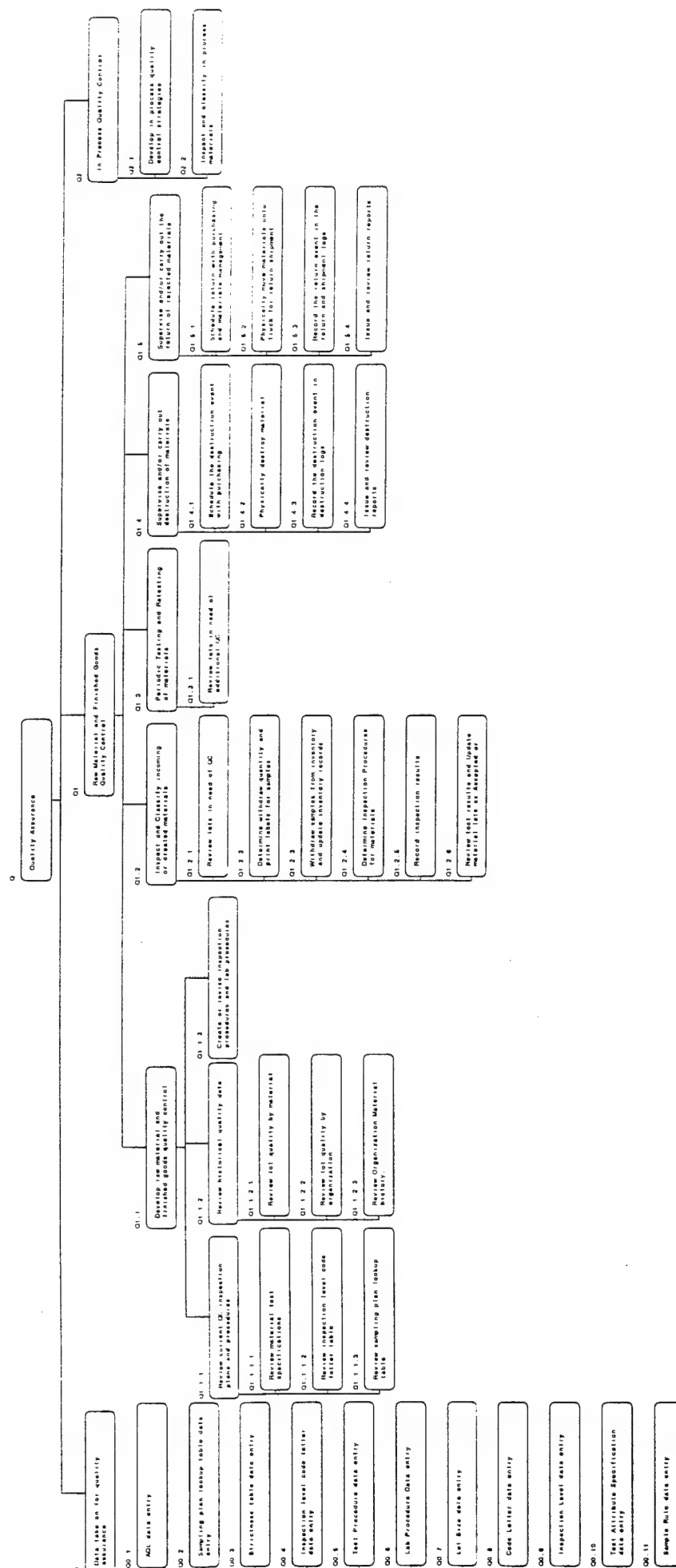
Page 1 of 1
Date 28-JUN-94

```
+--- Material Lots -----+
|
| Material Id: 1           Description: Reformed Beef Cubes 5/8"
|
| Organiz. Id: 3          Organ. Name: Herman Alpert Co., Inc.
|
| Lot Number: %                               Create Date/Time:
|                                     Starting      Ending
| Create Quantity:                01-JAN-01      28-JUN-94
|
+-----+
| Directions:
|
| - Fill in the fields with values required for the report.
| - Use wilcards (%) to indicate more than one value is acceptable.
| - Press [Accept/Commit] to run the report.
| - Report will be saved in file: LOTRES3.lis
|
+-----+
```

The ending date and time the lot was created.

Figure 28: Quality Assurance | Reporting | Lot Defects by Test Procedure Report Screen

Appendix I



Appendix II

Function to Entity Matrix Report

Oracle CASE*Dictionary
Function to Entity Matrix

- **Function : Q0.1**

Definition: AQL data entry

Entity	Create	Retrieve	Update	Delete
-----	-----	-----	-----	-----
ACCEPTABLE QUALITY LEVEL	Y	Y	Y	Y

- **Function : Q0.10**

Definition: Test Attribute Specification data entry

Entity	Create	Retrieve	Update	Delete
-----	-----	-----	-----	-----
TEST ATTRIBUTE SPECIFICATION	Y	Y	Y	Y

- **Function : Q0.11**

Definition: Sample Rule data entry

Entity	Create	Retrieve	Update	Delete
-----	-----	-----	-----	-----
SAMPLE RULE	Y	Y	Y	Y
SAMPLE RULE DETAILS	Y	Y	Y	Y

- **Function : Q0.2**

Definition: Sampling plan lookup table data entry

Entity	Create	Retrieve	Update	Delete
-----	-----	-----	-----	-----
SAMPLING PLAN LOOKUP TABLE	Y	Y	Y	Y

- **Function : Q0.3**

Definition: Strictness table data entry

Entity	Create	Retrieve	Update	Delete
-----	-----	-----	-----	-----
STRICTNESS	Y	Y	Y	Y

- **Function : Q0.4**

Definition: Inspection level code letter data entry

Entity	Create	Retrieve	Update	Delete
INSPECTION LEVEL CODE LETTER	Y	Y	Y	Y

- **Function : Q0.5**

Definition: Test Procedure data entry

Entity	Create	Retrieve	Update	Delete
TEST PROCEDURE	Y	Y	Y	Y

- **Function : Q0.6**

Definition: Lab Procedure Data entry

Entity	Create	Retrieve	Update	Delete
LAB PROCEDURE DETAIL	Y	Y	Y	Y

- **Function : Q0.7**

Definition: Lot Size data entry

Entity	Create	Retrieve	Update	Delete
LOT SIZE	Y	Y	Y	Y

- **Function : Q0.8**

Definition: Code Letter data entry

Entity	Create	Retrieve	Update	Delete
CODE LETTER	Y	Y	Y	Y

- **Function : Q0.9**

Definition: Inspection Level data entry

Entity	Create	Retrieve	Update	Delete
INSPECTION LEVEL	Y	Y	Y	Y

- **Function : Q1.1.1.1**

Definition: Review material test specifications

Entity	Create	Retrieve	Update	Delete
MATERIAL		Y		
MATERIAL TEST SPECIFICATION	Y	Y	Y	
TEST PROCEDURE		Y		

- **Function : Q1.1.1.2**

Definition: Review inspection level code letter table

Entity	Create	Retrieve	Update	Delete
INSPECTION LEVEL CODE LETTER	Y	Y	Y	Y

- **Function : Q1.1.1.3**

Definition: Review sampling plan lookup table

Entity	Create	Retrieve	Update	Delete
SAMPLING PLAN LOOKUP TABLE	Y	Y	Y	Y

- **Function : Q1.1.2.1**

Definition: Review lot quality by material (report)

Entity	Create	Retrieve	Update	Delete
MATERIAL		Y		
MATERIAL LOT		Y		
ORGANIZATION		Y		
ORGANIZATION MATERIAL		Y		

- **Function : Q1.1.2.2**

Definition: Review lot quality by organization (report)

Entity	Create	Retrieve	Update	Delete
MATERIAL		Y		
MATERIAL LOT		Y		
ORGANIZATION		Y		
ORGANIZATION MATERIAL		Y		

- **Function : Q1.1.2.3**

Definition: Review Organization Material history (report)

Entity	Create	Retrieve	Update	Delete
MATERIAL		Y		
ORGANIZATION		Y		
ORGANIZATION MATERIAL		Y		
ORGANIZATION MATERIAL HISTORY		Y		

- **Function : Q1.1.3**

Definition: Create or revise inspection procedures and lab procedures

Entity	Create	Retrieve	Update	Delete
LAB PROCEDURE DETAIL		Y	Y	
PROCEDURE CROSS REFERENCE	Y	Y	Y	
TEST PROCEDURE		Y	Y	

- **Function : Q1.2.1**

Definition: Review lots in need of QC

Entity	Create	Retrieve	Update	Delete
MATERIAL		Y		
MATERIAL LOT		Y	Y	
MATERIAL LOT LOCATION		Y	Y	
ORGANIZATION MATERIAL		Y		

- **Function : Q1.2.4**

Definition: Determine Inspection Procedures for materials

Entity	Create	Retrieve	Update	Delete
MATERIAL		Y		
MATERIAL TEST SPECIFICATION		Y		
TEST PROCEDURE		Y		

- **Function : Q1.2.5**

Definition: Record inspection results

Entity	Create	Retrieve	Update	Delete
MATERIAL LOT		Y		
MATERIAL TEST RESULT	Y	Y	Y	
ORGANIZATION		Y		
PERSON		Y		
SAMPLE INSTANCE	Y	Y	Y	
SAMPLE RULE		Y		
SAMPLING PLAN LOOKUP TABLE		Y		
STRICTNESS		Y		
TEST PROCEDURE		Y		

• **Function : Q1.2.6**

Definition: Review test results and Update material lots as Accepted or rejected

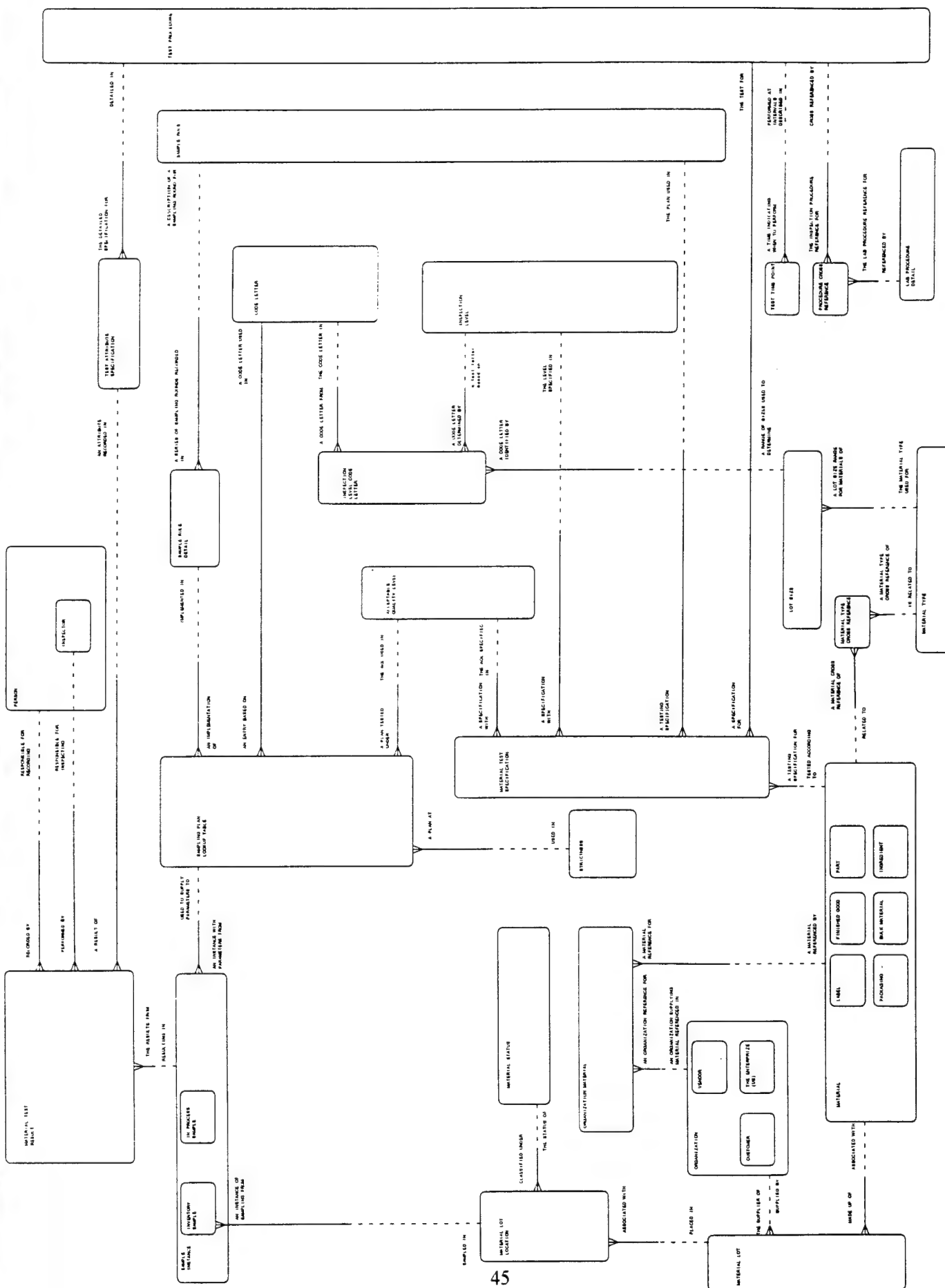
Entity	Create	Retrieve	Update	Delete
MATERIAL		Y		
MATERIAL LOT		Y	Y	
MATERIAL TEST RESULT		Y		

• **Function : Q1.3.1**

Definition: Review lots in need of additional QC

Entity	Create	Retrieve	Update	Delete
MATERIAL		Y		
MATERIAL LOT		Y		
MATERIAL STATE LOGS		Y		

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Appendix IV Entity Definition Report

Oracle CASE*Dictionary
Entity Definitions

- **ACCEPTABLE QUALITY LEVEL**

The quality level associated with a given material. Determines the levels of defects tolerated.

- **CODE LETTER**

Code letters are determined by lot size and inspection level. Each code letter is then used in the master lookup table for sample size and defect level information.

- **INSPECTION LEVEL**

A special or general level of inspection for the product. The inspection level for a given product is determined by the QA personnel. This entity hold the various levels and the descriptions of each level. Special inspection levels include: S-1, S-2, S-3, S-4, S-5. General inspection levels include: G-1, G-2 and G-3.

- **INSPECTION LEVEL CODE LETTER**

The table which holds the code letters determined by the inspection level and the lot size. Note that this entity has no native attributes. All are foreign keys.

- **INSPECTOR**

An employee who is authorized to inspect raw materials and finished goods for defects.

- **INVENTORY SAMPLE**

An instance of a sample taken from a static lot. Raw material lots and finished good lots are in this category.

- **LAB PROCEDURE DETAIL**

The details of the laboratory procedures to perform for a given inspection procedure.

- **LOT SIZE**

A table of lot size ranges for testing purposes. The lot sizes are given in sample units. This refers to the size of an individual sample for a given material.

- **MATERIAL**

The ingredients, packaging, parts, and supplies ordered by the enterprise from vendors. These are used to produce products, repair and maintain machines and.

- **MATERIAL LOT**

Lots of Raw materials sent from vendors and received, stored and used in production by the enterprise.

- **MATERIAL STATE**

A group of material states. (Ex. In QC, Accepted, Rejected, and Run out)

- **MATERIAL STATE LOG**

A record of all states changes for a material lot.

- **MATERIAL STATUS**

The STATUS is an entity to identify the location status in which materials remain. Statuses will vary with states. Statuses include accepted, in-transit, spoiled, return, destroyed, etc.

- **MATERIAL STATUS LOG**

A record of all status changes on a given lot location.

- **MATERIAL TEST RESULT**

A record of the quality control tests performed on material lots.

- **MATERIAL TEST SPECIFICATION**

The testing specification for the raw material. Includes the inspection procedure, material, AQL, sample unit size and the sampling rule.

- **MATERIAL TYPE**

The different types of materials, i.e., finished goods, raw materials.

- **MATERIAL TYPE CROSS REFERENCE**

A given material type is related to multiple materials via this cross reference.

- **ORGANIZATION**

A supertype entity for any organization. Sub-types include vendor, customer and the enterprise.

- **ORGANIZATION MATERIAL**

A Cross reference between the organization and the material entities that enforces a one to one correspondence.

- **ORGANIZATION MATERIAL HISTORY**

A temporal entity holding the historical events of an organization for a particular material. Includes whether or not the organization has approval to supply the material and the current strictness rating.

- **PROCEDURE CROSS REFERENCE**

A Lab Procedure / Inspection procedure cross reference. Includes a sequence number for performing each lab procedure associated with an inspection procedure.

- **QUALITY CONTROL MANAGER**

The manager of the quality control area.

- **SAMPLE INSTANCE**

An instance of one sample of a given test instance.

- **SAMPLE RULE**

The master records for sampling rules. Includes an identifier and a description.

- **SAMPLE RULE DETAIL**

Details on the sampling plan including number of samples to take, acceptance and rejection levels, AQL, etc.

- **SAMPLING PLAN LOOKUP TABLE**

The master table for determining sample size and acceptance and rejection levels.

- **STRICTNESS**

The strictness of the sampling plan for the vendor. Examples are Tightened, Normal and Reduced.

- **TEST ATTRIBUTE SPECIFICATION**

The specifications for each inspection procedure.

- **TEST PROCEDURE**

An entity containing a description of how the quality control test is performed.

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**COMBAT RATION
ADVANCED MANUFACTURING
TECHNOLOGY DEMONSTRATION
(CRAMTD)**

Level 2 Automation of the Tray Pack Line

Technical Working Paper (TWP) 88

**G. Alpan, T.O. Boucher and D. Livingston
Department of Industrial Engineering**

August 1994

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1. Introduction:

This document is an interim report concerning task item 3.5.2 of STP #16, Implementation of Integrated Manufacturing. That task item requires the implementation of an automation strategy at level 2 for the Tray Pack Line. Specifically, automatic data acquisition and computer integration are the main focal points of this report.

The architecture of the plan is to acquire data from the production line using the Allen Bradley Series 5 Programmable Logic Controller (PLC) and then pass it to the Shop Floor PC. Finally, the data will be uploaded to a central data base for records keeping. The data that are collected can be classified into four groups:

- 1) Tray weights and material usage
- 2) Tray counts
- 3) Downtime and fault conditions
- 4) Production rates and line efficiency

As the first step of level 2 automation, related data should be passed from the tray pack line to the PLC. To achieve this, the existing ladder diagram is modified and a new input module had to be installed because none of the above listed data groups, except for the "Fault Conditions", were previously collected by the PLC. Section 3 describes the modifications and PLC implementation in detail.

The second step of the automatic data acquisition is to pass the data from the PLC to the shop floor PC. FIX DMACS, an industrial automation software, is used to achieve this end. Through a graphical user interface of FIX DMACS, it is possible to display and manipulate real-time data as well as provide some supervisory control of the line. A brief discussion of the software is given in section 7.

2. Overview of Tray Pack Line

The Tray Pack Line controller is an Allen Bradley PLC 5/12, which is housed in a panel adjacent to the automatic ladder. The AB PLC 5/12 has overall supervision of the operating cycle of the Yaguchi Seamer as well as various activities along the conveyor line. Below is a chart detailing pertinent PLC inputs. Refer to Figure 1 for the locations corresponding to the PLC inputs.

<u>Purpose</u>	<u>Input</u>	<u>Location</u>	<u>PLC Input</u>
Motor overload main drive	thermal switch	Seamer, G	I:002/00
Motor overload vacuum pump	thermal switch	Phasing Conv'r, E	I:002/01
Motor overload lid conveyor	thermal switch	Lid Conveyor, I	I:002/02
Motor overload filler conveyor	thermal switch	Filling Conv'r, A	I:002/03
Motor overload phasing conveyor	thermal switch	Phasing Conv'r, E	I:002/04
Motor overload spacing conveyor	thermal switch	Spacing Conv'r, E	I:002/05
Motor overload checkweigh	thermal switch	Checkweigh, C	I:002/06
Motor overload reject diverter	thermal switch	Reject Diverter, D	I:002/07
Motor overload reject lane	thermal switch	Reject Lane, F	I:002/10
Wheel in / out safety sealer	limit switch	Seamer, G	I:002/11
Over torque safety sealer	limit switch	Seamer, G	I:002/12
No vacuum	limit switch	Phasing Conv'r, E	I:002/13
No cover / no body	limit switch	Discharge Conv'r, H	I:002/14
No cover / no body	limit switch	Discharge Conv'r, H	I:002/15
Carrier fault	limit switch	Phasing Conv'r, E	I:002/16
Cover & body check	limit switch	Discharge Conv'r, H	I:002/17
Lid position	limit switch	Discharge Conv'r, H	I:003/00
Lid not in place	limit switch	Discharge Conv'r, H	I:003/02
System start	push button	Panel, Z	I:003/03
System stop	push button	Panel, Z	I:003/04
Run/Count	selector switch	Panel, Z	I:003/05
Fault reset	push button	Panel, Z	I:003/06
Auto / Man	selector switch	Panel, Z	I:003/07
Individual Auto / Man	selector switch	Panel, Z	I:003/12
Control Power On	contact relay	Panel, Z	I:003/17
Discharge conveyor full	photosensor	Discharge Conv'r, H	I:004/00
Reject lane full	photosensor	Reject Lane, F	I:004/01
Infeed to reject conveyor	photosensor	Reject Lane, F	I:004/02
Infeed to reject diverter	photosensor	Reject Diverter, D	I:004/03

Mound detection	fiber optic	Checkweigh, C	I:004/04
Zero speed phasing conveyor		Phasing Conv'r, E	I:004/06
<u>Purpose</u>		<u>Location</u>	<u>PLC Input</u>
Zero speed spacing conveyor		Spacing Conv'r, B	I:004/07
Zero speed checkweigh		Checkweigh, C	I:004/10
Zero speed reject diverter		Reject Diverter, D	I:004/11
Zero speed reject lane		Reject Lane, F	I:004/12
Underweight detection		Checkweigh, C	I:004/13

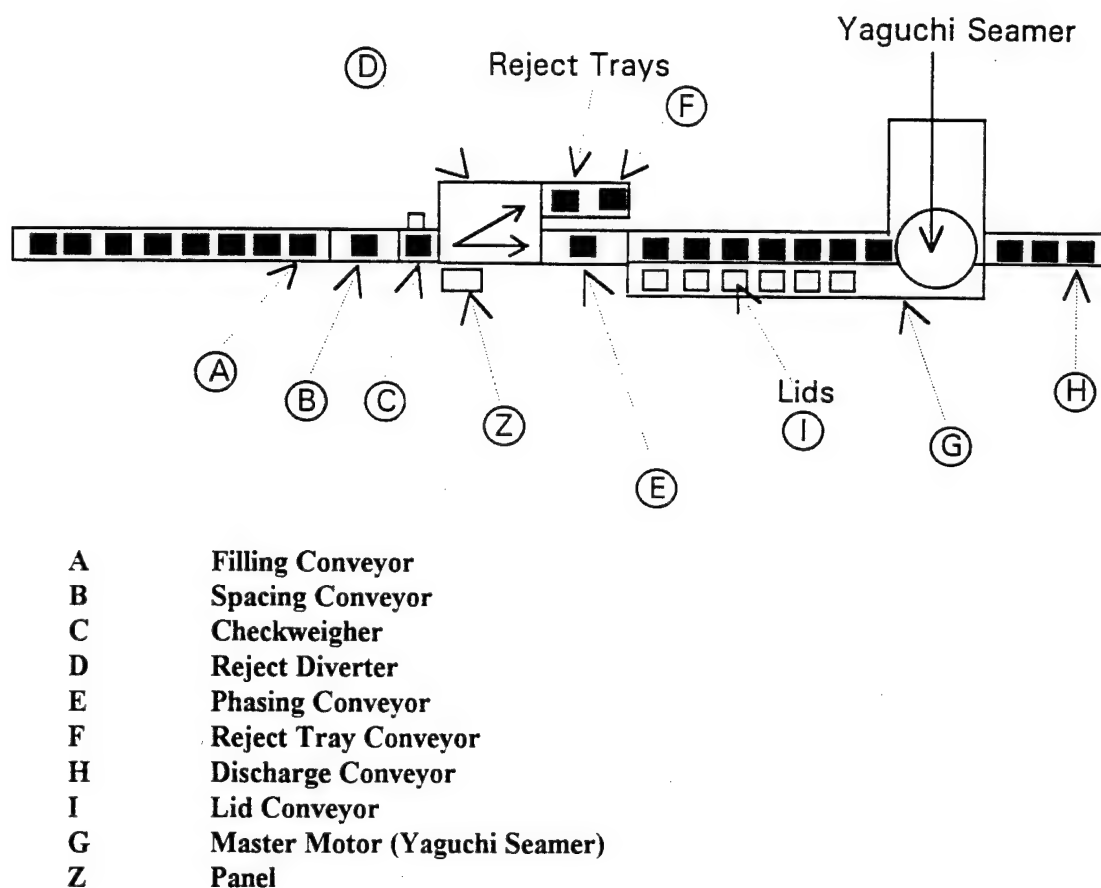


Figure 1 : Tray Pack Conveyor

The inputs listed above are pertinent to the automatic data collection effort. These inputs are continually referred to throughout this document.

3. Automatic Data Collection - Monitoring Tray Weights

Several software and hardware changes were implemented to enable data to be collected by the PLC. The data included: tray weights and material usage; tray counts; downtime and fault conditions; and production rates and line efficiencies.

Data acquisition of tray weights entails passing the weights taken by the checkweigher to the PLC and then into the Shop Floor PC for records keeping. The PLC also records the number of underweight and overweight trays. A fiber optic sensor on the checkweigher conveyor monitors mounding of the tray. This data is also passed to the PLC, and an appropriate count is incremented.

Tray counts are collected at two points in the line. All trays pass by a photo sensor at the end of the checkweigher conveyor. Seamed and completed trays are reported by a proximity sensor on the discharge conveyor of the seamer. These trays are considered seamed trays. Overweight/underweight or mounded trays are considered defective (bad) and diverted. The defective trays are counted as the difference between the total number of seamed trays and total number of trays that leave the checkweigher.

Downtime and fault conditions are kept track of by latching and unlatching certain bits within the AB PLC 5/12. These bits will start and stop timers within the PLC, enabling downtime, uptime, and other critical statistics to be kept.

Production rates can be computed as the number of seamed trays divided by the total time of production. Other rates and figures can also be calculated to determine efficiency of the line.

The results of the above data collection and computations are presented in a user friendly format to the operators and supervisors of the production line. FIX DMACS, an object oriented presentation package, is the PC based SCADA (Supervisory Control And Data Acquisition) software used to collect the necessary data from the AB 5/12 PLC and display that data to the plant floor personnel.

In order to provide FIX DMACS with the necessary data, the existing ladder logic for the tray pack line was modified in several ways. First, the tray weights from the checkweigher are captured in a register in the PLC. In order to accomplish this, a new input module was installed in the AB PLC 5/12 to which the binary coded decimal (BCD) output of the checkweigher, representing the weights, was sent. Secondly, counters are added to keep track of the total trays, rejected trays, and seamed (good) trays. Finally, timers are added to keep track of the total uptime, total downtime, and total idle time. When changing the existing ladder diagram, the principle employed was to minimize changes to the ladder diagram by maximizing the use of FIX DMACS. For example, in manipulating data, any necessary calculations are performed in FIX DMACS rather than the ladder diagram. This allows the PLC to monitor the production line in a more efficient manner.

In order to display the tray weights, FIX DMACS must retrieve the weights from a register in the PLC. Therefore, the PLC must capture the tray weights from the checkweigher in a register. Tray weights from the checkweigher are captured in I:011 each time a tray is weighed and then moved to register N11:0. Figure 2 shows the additions to the ladder that transfer the tray weights to register N11:0.

In Rung 115, bit B3/221 goes from high (1) to low (0) when a new tray weight is received. When B3/221 is disabled, a timer is enabled for 1.5 seconds in Rung 116. After 1.5 seconds, Rung 117 moves the new weight stored in I:011 to N11:0 and Rung 118 resets the timer. In order for the PLC to be able to capture the data, additional wiring needed to be performed to pass the data from the Hi-Speed Checkweigher to the AB PLC 5/12.

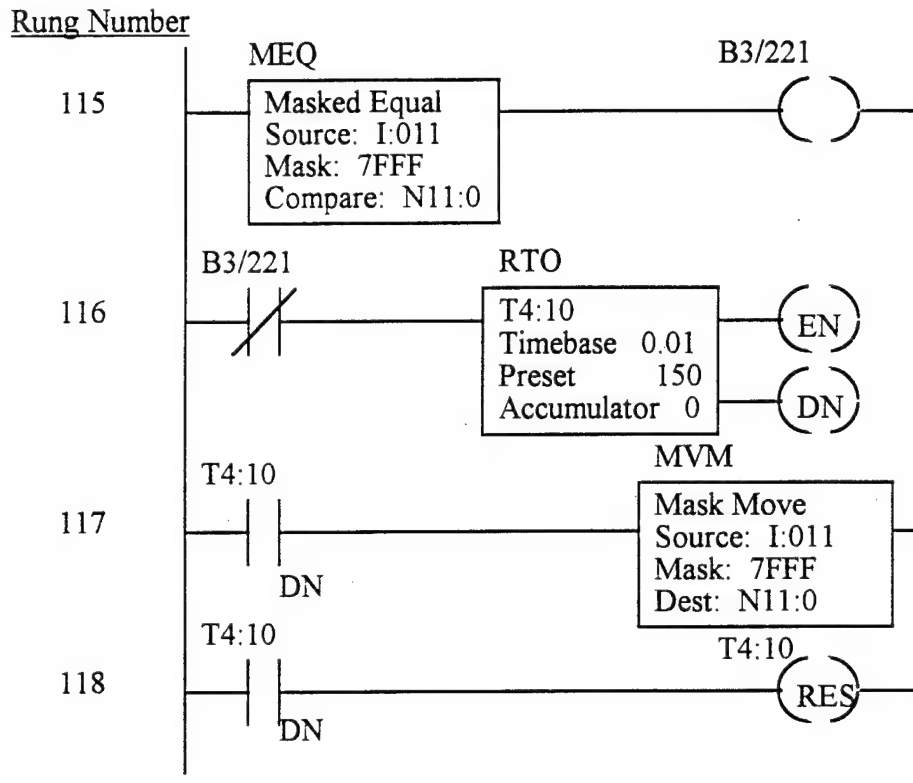


Figure 2: Transfer of Tray Weights to PLC Register

In order to obtain the tray weight in address I:011, communications had to be installed between the checkweigher and the Allen Bradley PLC. The checkweigher has an output port that provides binary coded decimal (BCD) data of the weight of each tray that passes over the checkweigher. The BCD data is composed of 4 sets of numbers each with 4 bits for a total of 16 bits. Using an Allen-Bradley 1771-IGD 16-point Input Module, with TTL voltage levels, the BCD data was passed to the AB PLC 5/12. Table 1 is a cross reference for the wiring. (The signal names were taken from Hi-Speed's schematic 'Schematic - BCD to Serial PCB', Dwg. no. C2-65-118)

As can be seen, the most significant bit of the BCD output is not utilized. This bit is not necessary as the weight of the tray should never necessitate the use of that bit. If ever the weight of the tray should need the BCD '1000' MSB, an overweight would have

also been triggered. The last bit of the TTL module has been reserved for BCD ready, to indicate that the checkweigher is on-line and ready.

Checkweigher signal	Signal Name	Wire color used	TTL module input signal
J1-1	BCD '1' LSB	Yellow	00
J1-2	BCD '1'	White w/ Black	01
J1-3	BCD '1'	Orange	02
J1-4	BCD '1' MSB	Black	03
J1-5	BCD '10' LSB	White w/ Red	04
J1-6	BCD '10'	Red	05
J1-7	BCD '10'	Red w/ Yellow	06
J1-8	BCD '10' MSB	Red w/ Black	07
J1-9	BCD '100' LSB	White w/ Yellow	10
J1-10	BCD '100'	Grey	11
J1-11	BCD '100'	Purple	12
J1-12	BCD '100' MSB	Brown	13
J1-13	BCD '1000' LSB	White w/ Green	14
J1-14	BCD '1000'	White w/ Orange	15
J1-15	BCD '1000'	Green	16
J1-16	BCD '1000' MSB	Blue	not used
J1-17			
J1-18	BCD Ready	Pink	17
J1-30	Ground		GND

Table 1

Power for the TTL module is currently provided by an external power supply. Ground of the power supply is tied together with ground of the system. This power supply may be kept, and powered by the internal 110 volts supplied by the control panel, or another power source may be utilized. A transformer has been supplied to the technicians at CRAMTD. This transformer can be installed in the system, using the 24 VDC source available on the PLC power supply, transforming this voltage level to TTL specifications.

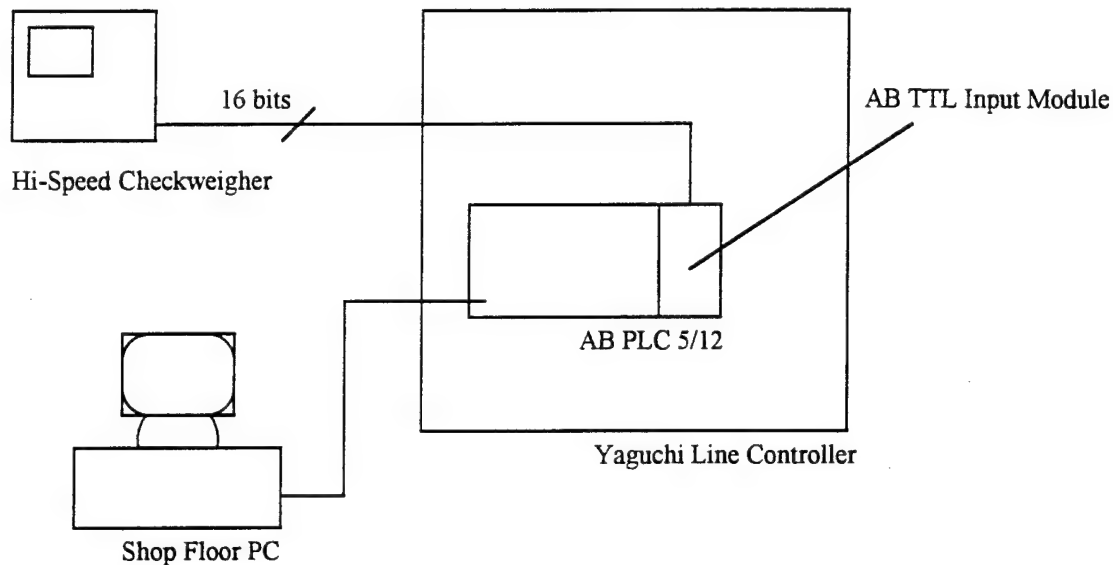


Figure 3: Communications between Checkweigher, PLC, and Shop Floor PC

Whenever the BCD data changes, a bit is then latched within the AB PLC 5/12. This bit then starts a RTO timer. After 1.50 seconds, the data on the input lines of the TTL input module is then passed into a data register. The 1.50 seconds delay is being used for the settling time of the BCD. Since the maximum speed of the Tray-Pack line is 30 trays per minute => 1 tray every two seconds, this 1.5 seconds is short enough such that the data in the register will not have yet been updated.

The data received by the AB TTL input module is passed onto the Shop Floor PC. This PC, running FIX DMACS, detects the latched bit and then picks the weight out of the rack itself. The data is then transformed by the FIX DMACS programming into the display image of the Shop Floor PC.

4. Automatic Data Collection - Monitoring Production Rates

The existing ladder diagram contained counters for total trays and underweight trays. When testing the tray pack line, the documentation of the Tray Pack Line control software for input I:4/3 and counter C5:1 was found to be incorrect. The existing ladder

diagram documents I:4/3 as the infeed of the diverter and C5:1 as the count of the trays entering the diverter (total rejected trays). In fact, I:4/3 is the infeed of both the diverter and phasing conveyor because the photoelectric sensor controlling I:4/3 is located just before trays are diverted to the reject lane. As a result, all trays pass the sensor enabling I:4/3. Therefore, referring to Rung 2:60 of the existing ladder diagram, C5:1 is the count of total trays. Also, the description of C5:2 is somewhat misleading. The existing ladder diagram describes C5:2 as the count of trays rejected, which leads one to believe C5:2 is the number of total rejects. C5:2 only counts trays rejected because they are underweight. It does not include those trays rejected for mounding.

Three counters were added to the existing ladder diagram. First, C5:3 counts the number of total trays rejected for mounding, as shown in figure 4. I:4/4 is used as a normally closed input to the counter. I:4/4 reads a fiber optic sensor whose beam is broken whenever a mounded tray passes. If the beam is broken, I:4/4 becomes de energized and C5:3 is incremented by one when I:4/4 closes again. Figure 4 shows the ladder logic counting for mounded trays.

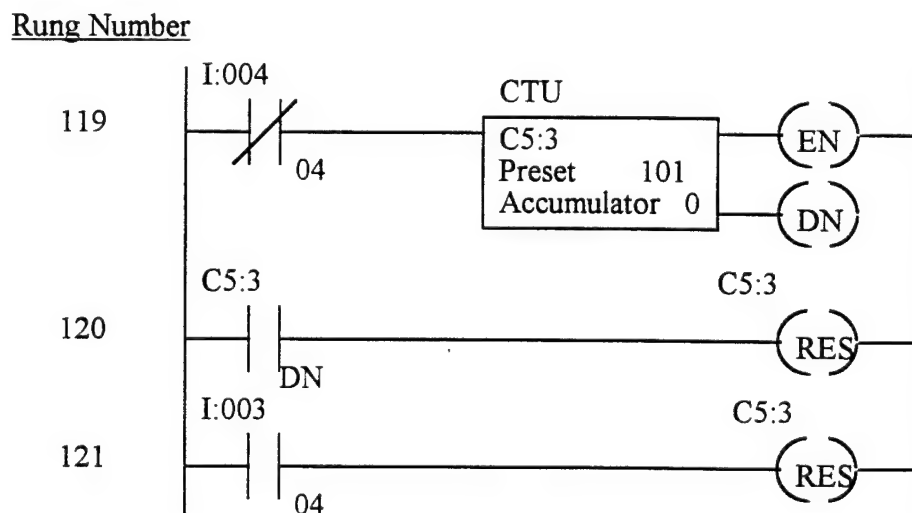


Figure 4: Ladder Diagram for Counting Mounded Trays

When a mounded tray passes the fiber optic sensor, I:4/4 becomes disabled and counter C5:3 is incremented by one in Rung 119. If the number of mounded trays exceeds 100, Rung 120 resets counter C5:3. Rung 121 allows the operator to reset the counter. A stop push-button on the panel enables I:3/4, which in turn, resets the counter. Therefore, the counter can be reset at the beginning of a shift.

Figure 5 shows the ladder logic for counting the number of seamed trays. Whenever a tray passes the sensor on the discharge conveyor, I:4/0 becomes energized and C5:5 is incremented by one. Whereas I:4/3 detects all trays (seamed and rejected), I:4/0 detects only acceptable seamed trays. Figure 5 shows the ladder logic counting acceptable trays. Finally, FIXDMACS gets the number of total rejects from C5:6. Note that figure 4 and 5 have a set input I:3/4. This is an operator push button that is used to zero these registers at the start of a shift.

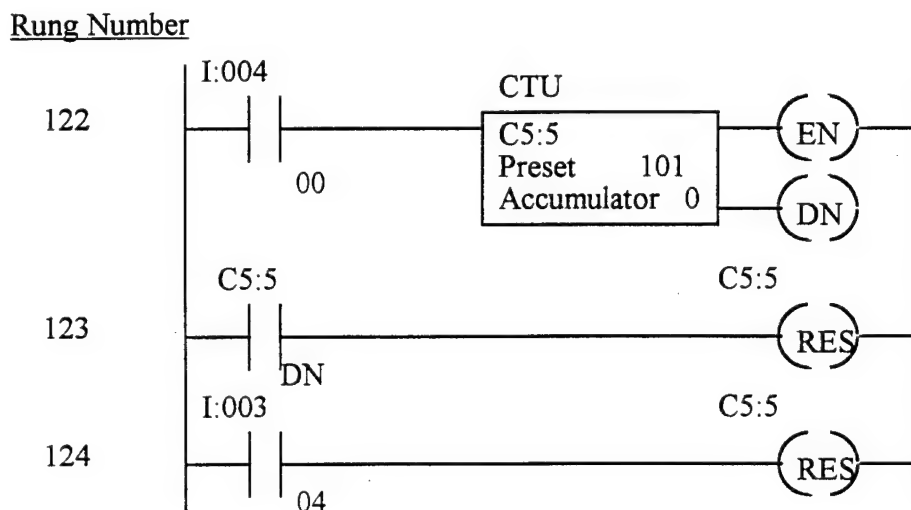


Figure 5: Ladder Diagram for Counting Total Seamed Trays

In Rung 122, counter C5:5 is incremented by one when a good tray passes the sensor controlling I:4/0. The counter is reset in rungs 123 and 124 when the number of acceptable trays reaches 101 or an operator pushes the stop push-button, respectively.

The ladder logic for counting total trays rejected is shown in Figure 6. To ensure that the counters would continue to count without resetting themselves during a work shift, a large preset is required. Therefore, assuming an 8-hour shift and maximum production speed of one tray every two seconds, the presets for counters C5:3, C5:5, and C5:6 should be set at 16,000. A photosensor on the reject lane enables I:4/2 whenever a tray passes causing counter C5:6 to increment in Rung 125. Rungs 126 and 127 reset the counter when the count reaches 101 or when an operator hits the stop push-button on the panel.

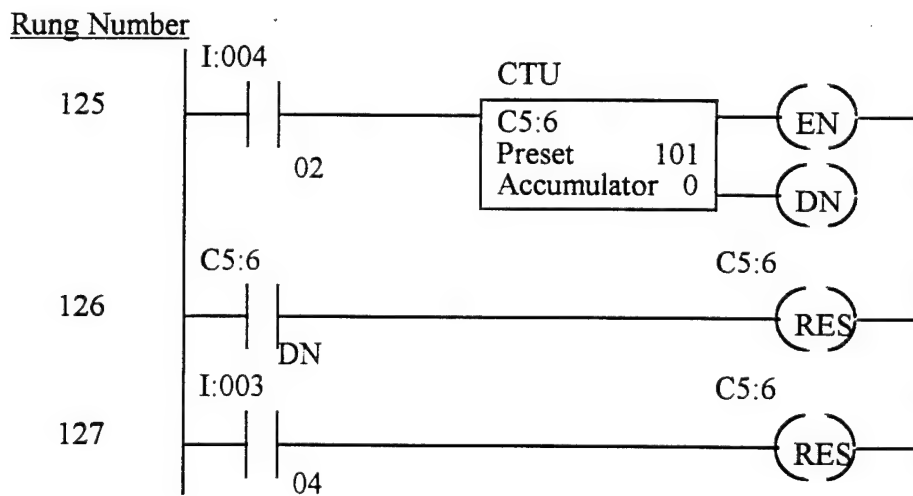


Figure 6: Ladder Diagram for Counting Total Rejected Trays

5. Automatic Data Collection - Monitoring Uptime and Downtime

In order to provide FIX DMACS with the total uptime, total downtime, and total idle time, three timers were added to the existing ladder diagram. In figure 7, the total uptime is captured in retentive timer T4:13. I:3/3 is the system start push button. When the operator pushes the push button to start the production line, timer T4:13 starts.

Referring to Rung 130, B3/25 is the system start relay, which is generated from rung 43. If B3/25 is energized, the system is up and running. Once B3/25 becomes de energized, timer T4:13 stops increasing. Since T4:13 is a retentive timer, the value will be stored in the timer until the timer is reset. Figure 7 shows the ladder logic for the total uptime.

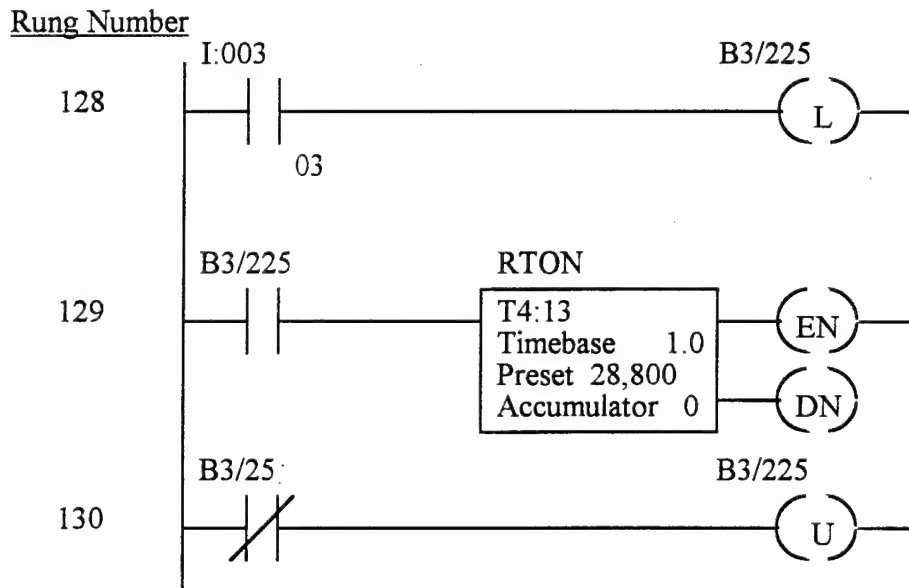


Figure 7: Ladder Diagram Capturing Total Uptime

In Rung 128, bit B3/225 is latched when an operator pushes the system start push-button. As shown in Rung 129, the timer T4:13 is on while B3/225 is enabled. When the system stops running, the system start relay B3/25 disables, which in turn, unlocks B3/225 in Rung 130 and stops timer T4:13.

Timer T4:11 captures total downtime, as shown in figure 8. B3/24 is the master safety relay. When B3/24 is energized, the production line is in working order. C5:4[DN] is energized when the reject lane is full. Similarly, B3/32 is energized when the discharge conveyor is full. In Rung 131 of Figure 8, T4:11 increments when either B3/24 is not energized, C5:4[DN] is energized, or B3/32 is energized. In other words, downtime is captured when the production line is not functioning or either the reject lane or discharge

conveyor is full. The timer is reset in Rung 132 when an operator pushes the system stop push-button.

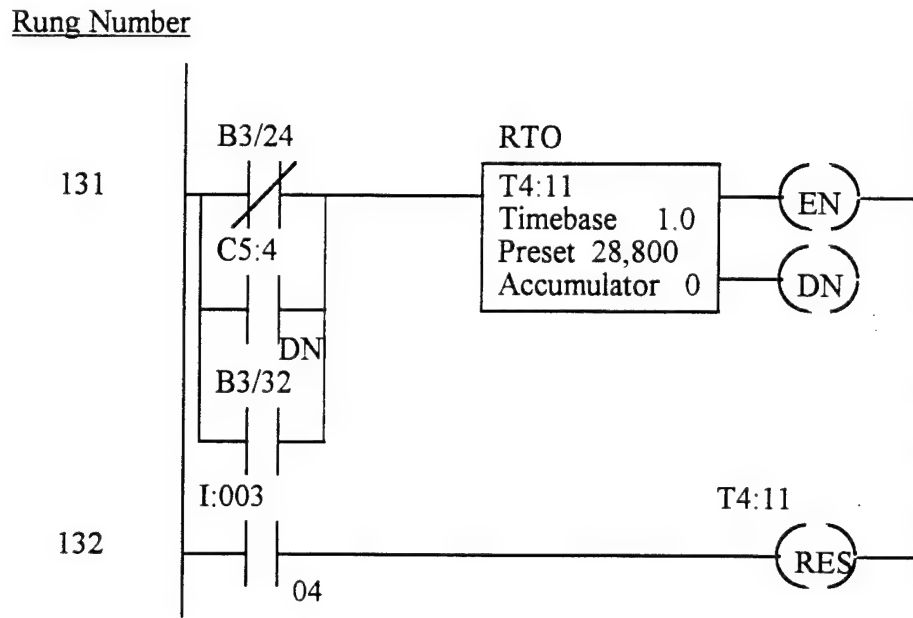


Figure 8: Ladder Diagram Capturing Total Downtime

As stated previously, idle time is the time the system is available but not running. Timer T4:12, shown in figure 9, captures idle time. When B3/25 is not energized and there are no fault conditions, timer T4:12 is incremented. Figure 9 shows the ladder logic for idle time. In Rung 133, timer T4:12 is enabled when B3/25 is disabled but everything is functioning as indicated by the other bits. In Rung 134, the system stop push-button resets the timer.

At the beginning of each work shift, the counters and retentive timers should be reset to zero. Currently, I:003/04 is used to reset the counters and retentive timers. I:003/04 is the system stop push button. Until another push button is incorporated to reset the counters and timers, I:003/04 is the best choice available. The system start push button (I:003/03) was not chosen because it is used to start the line during a shift if the

line stops for a fault condition. In this case, the counters and timers would be reset during a shift if any fault conditions occur.

Rung Number

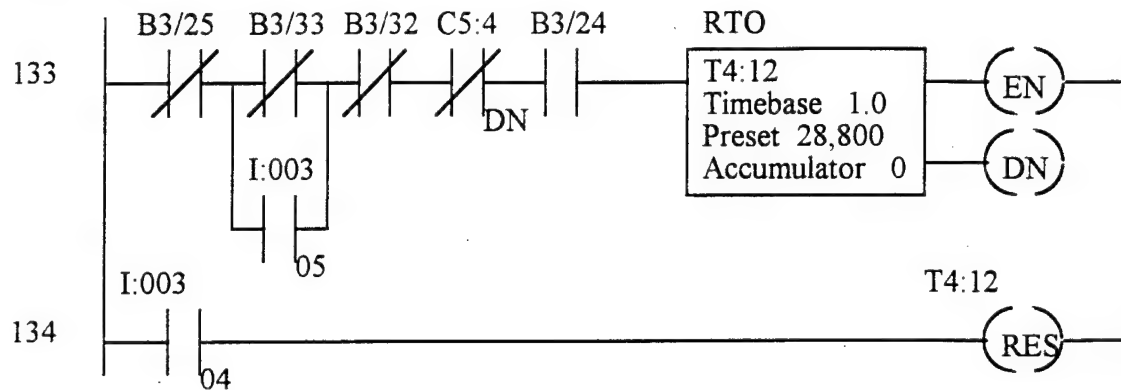


Figure 9: Ladder Diagram Capturing Idle Time

In our final implementation, we will probably use FIX DMACS to reset counters and timers at the beginning of a shift. This will be done by setting and resetting a bit in PLC memory. That bit will replace I:003/04 on rungs 121, 124, 127, 132, and 134.

In order to minimize modifications to the existing ladder diagram, the production rates and line efficiency will be computed in FIX DMACS. Because the set point speed of the production line is currently not available to the PLC as data, the PLC cannot record the set point speed. As a result, line efficiency will be calculated as seamed trays (C5:5) divided by total trays (C5:1). Production rates can be calculated as number of seamed trays (C5:5) divided by total uptime (T4:13).

6. Automatic Data Collection - Monitoring Fault Conditions

The shop floor PC will also highlight fault conditions. Figure 10 displays the overall structure of the failure mode by bit and rung in the ladder logic.

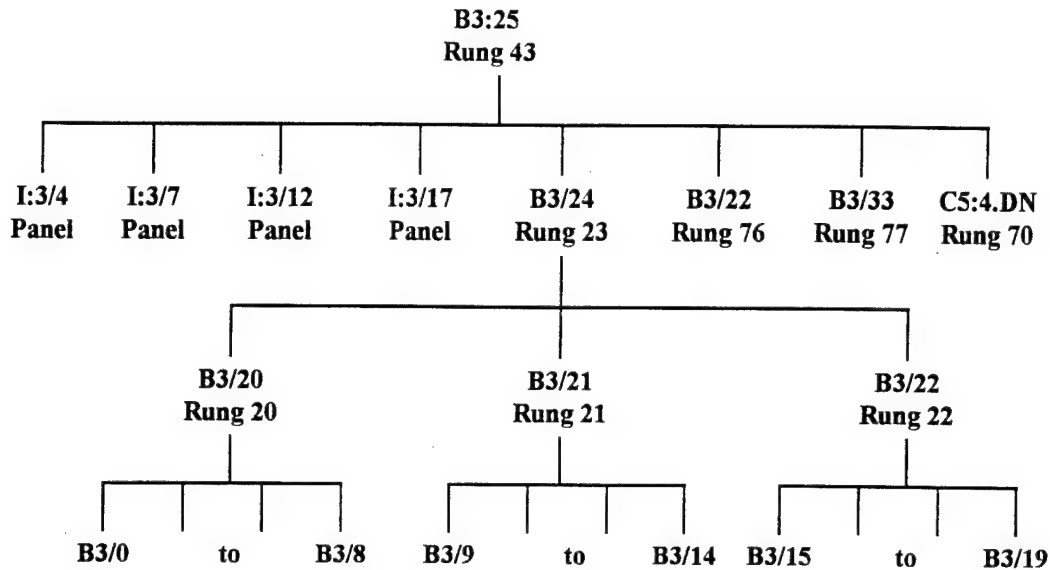


Figure 10: Overall Structure of Failure Mode

Rung 43, shown in figure 11, controls whether the system is up or down. When B3:25 is enabled, the system is up and the conveyors are running. Otherwise, the system is down. When the system goes down, the fault condition can be traced back to rung 43. All of the bits enabling B3:25 (from rung 43) are on level 2 of figure 10.

Rung Number

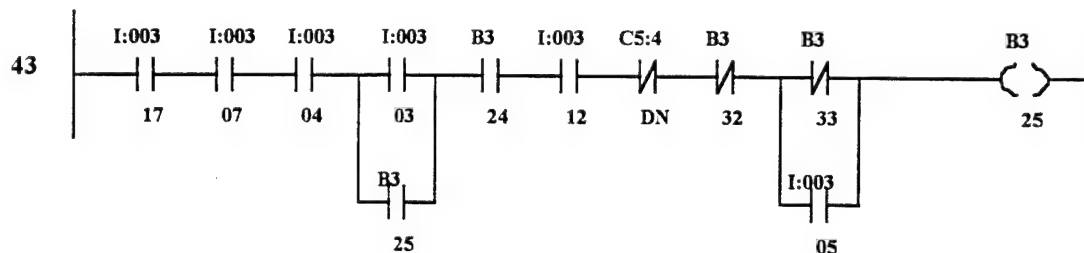


Figure 11: Ladder Diagram Controlling the Up/Down Cycle

The operator can control whether the system is up from several inputs in the form of push buttons. In order to start the system, the operator must push the system start push-button I:003/03 on the panel. Also, the control power must be on (I:003/17). Finally, the automatic/manual switches must be set in the automatic state. If in the automatic state, the switches will enable bits I:003/07 and I:003/12. The operator can also specify the number of tray packs to be produced. The run/count switch, controlling I:003/05, allows the operator to preset the number of trays to be produced. If I:003/05 is disabled, the production line will only run until the preset number of trays are produced causing B3/33 to enable and B3/25 to disable.

The master safety relay B3:24 is enabled when the system is in working order. Rung 23, shown in figure 12, enables B3:24 when the motor overload (B3/20), machine fault (B3/21), and zero speed (B3/22) master safety relays are enabled. In figure 13, rung 20 controls B3/20. If B3/20 is disabled, a motor overload has occurred and the specific area being overloaded can be traced to rung 20. Bits B3/0 to B3/8 narrow the overload condition to the specific area on the line. If, for example, the main drive has a motor overload, B3/0 would become enabled causing B3/20 to become disabled. Notice that bits B3/0 to B3/8 must all be disabled to enable B3/20. Therefore, any overload condition will disable B3/20 and in turn B3/24 and B3/25.

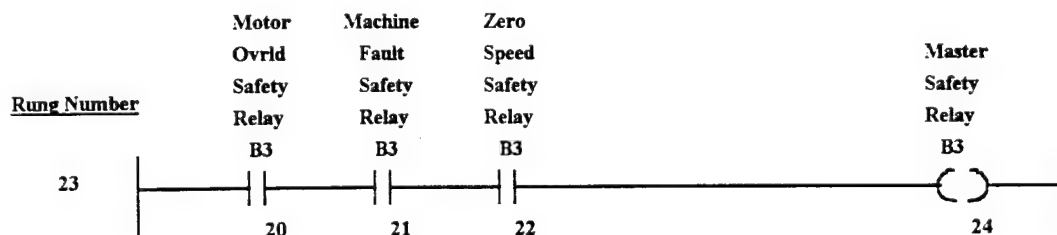


Figure 12: Ladder Diagram Controlling Master Safety Relay

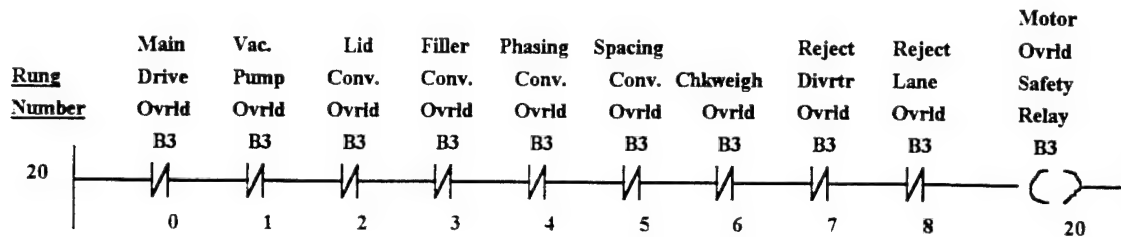


Figure 13: Ladder Diagram Detecting Motor Overload Faults

All machine faults are detected by bit B3/21 in rung 21, shown in figure 14. These fault conditions include wheel in / wheel out (B3/9), over torque (B3/10), no vacuum (B3/11), no cover / no body (B3/12), carrier fault (B3/13), and lid position (B3/14). If any of the above machine fault conditions occur, B3/21 will become disabled causing B3/24 and B3/25 to become disabled.

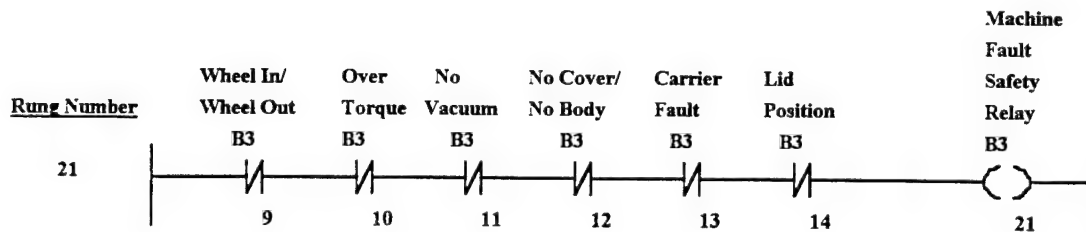


Figure 14: Ladder Diagram Detecting Machine Faults

In figure 15, bit B3/22 becomes disabled when any zero speed fault conditions occur. B3/15 to B3/19 pinpoint the specific area that a zero speed fault condition has occurred. For example, if the phasing conveyor has a zero speed condition, B3/15 becomes enabled causing B3/22 to become disabled.

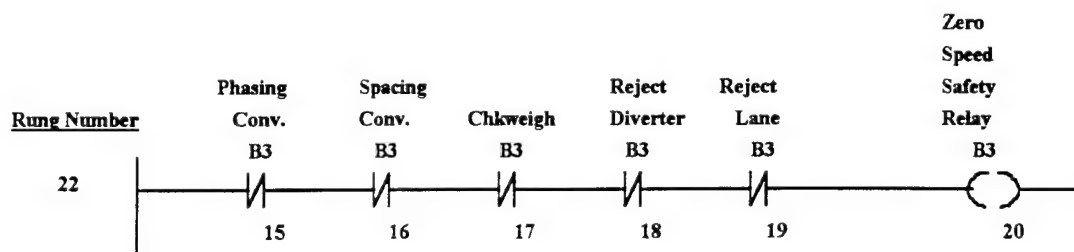


Figure 15: Ladder Diagram Detecting Zero Speed Faults

7. Automatic Data Collection - FIX DMACS Implementation

In order to support the shop-floor data collection effort, an industrial automation software called FIX DMACS is used on the Tray Pack Assembly Line. FIX stands for Fully Integrated Control System and DMACS stands for Distributed Manufacturing Automation and Control Software. FIX DMACS, an object oriented presentation package, is the PC based SCADA (supervisory control and data acquisition) software used to collect the necessary data from the AB 5/12 PLC and display that data to the plant floor personnel. FIX DMACS provides the personnel with the raw data from the PLC in an easily understandable format.

FIX DMACS uses a graphical user interface to acquire, present, and manage the data. In addition to displaying the real-time plant-floor data, FIX DMACS provides three other SCADA functions: supervisory control, alarming, and control. After retrieving data, FIX DMACS manipulates and processes the data according to the user's needs. FIX DMACS can not only retrieve and process data from programmable controllers but also can write data to the controllers. This two-way link provides plant floor personnel with the ability to control the process from the computer. Through supervisory control, FIX DMACS allows operators to change set points and other key values from the computer. Alarming is the ability to recognize exceptional events and immediately report those events. Finally, FIX DMACS can control the process by automatically applying algorithms that adjust process values, maintaining those values within set limits.

FIX DMACS is flexible enough to operate in a distributed processing environment or a centralized processing environment. FIX DMACS can be used for applications requiring only one node or applications requiring distributed processing over a network. In addition, processing can be time-based or exception-based. If time-based processing is chosen, data is processed every time period specified. If exception-based processing is chosen, data is processed when an event occurs. The events can be: data changes, unsolicited messages from the process hardware, operator actions, or software applications.

The basic architecture of FIX DMACS, shown in Figure 16, consists of the following: I/O driver; Driver Image Table (DIT); Scan, Alarm, and Control (SAC) program; database; internal database access software; and the software applications. The I/O driver is the software interface to the PLC that reads or writes data from/to the registers. The user specifies the necessary registers using the I/O driver configuration task. The Driver Image Table consists of the data from the specified registers. Each block in the DIT is called a poll record. A poll record is created in the I/O driver configuration task by specifying its starting address in the PLC and length. The length is the number of words. Therefore, a poll record can hold data from more than one address. Each poll record has a poll time, which is the rate that the DIT is updated by the I/O driver.

The Scan, Alarm, and Control program is the link between the DIT and the database. SAC does the following: transfers data from the DIT to the database or writes data to the DIT from the database, transforms the data into the necessary format for the database, generates alarm messages if the data is outside the alarm limits, identifies any exceptions, and executes the control logic of the process database.

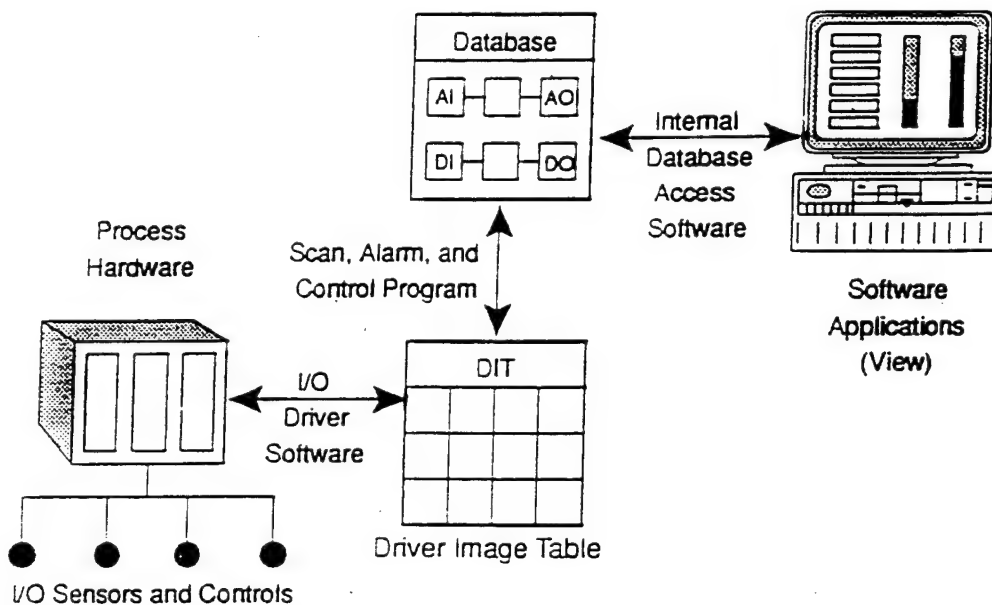


Figure 16: Basic Architecture of FIX DMACS

The process database manipulates and processes the raw data from the PLC according to the user's needs. The Database Builder program is used to create the database, which is made up of blocks and chains. A block performs a specific task using a coded set of process control instructions. A chain contains more than one block linked together to form a control loop. If, for example, you wanted to add the data of two data points together and write that value back to the PLC, the chain would consist of two Analog Input blocks connected to a Calculation block, which is connected to an Analog Output block. There are many different types of blocks, allowing one to manipulate the data in almost any conceivable way. Figure 17 shows an illustration of the process database.

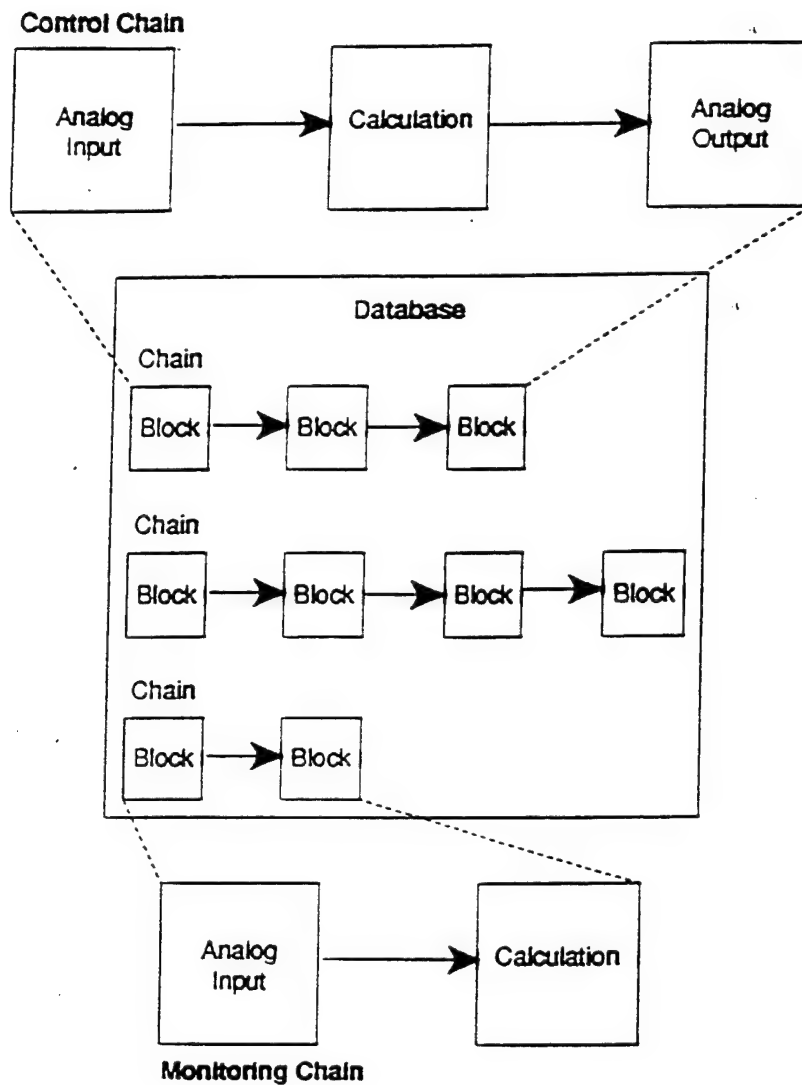


Figure 17: Database Blocks and Chains

The internal database access software transfers the data process by the database to the necessary software applications. The two graphics applications are Draw and View. The designer uses Draw to create the displays. View shows the displays changing in real-time as the processed data changes. Therefore, the plant personnel can monitor the production line from the computer display shown in View.

For the tray pack line, the computer screen developed using FIX DMACS displays several items. First, the screen shows the overall status of the production line by

displaying one of the following messages: system ready, system running, and system fault. If the production line is available but not running, the "system ready" message will appear in blue. If the production line is running, the "system running" message will appear in green. Finally, if the production line is stopped because of a system fault, the "system fault" message will appear in red.

Secondly, the FIX DMACS screen shows several different tray counts. These include total produced, total rejected, and total accepted. Furthermore, the total trays rejected are subdivided by rejection categories. Directly under the total rejected number, the screen shows the number rejected for underweight (insufficient material in the tray) and the number rejected for mounding (material in tray is piled too high for sealing).

Third, FIX DMACS displays the current tray's weight and whether the tray is accepted or rejected. After the checkweigher weighs a tray, that weight is displayed on the FIX DMACS screen directly under the tray counts. The weight remains on the screen until another tray is weighed, at which time the new weight is displayed. The computer screen also shows a picture of the production line below the tray weight. The acceptance/rejection status of the current tray is displayed on the production line. If the current tray is acceptable, a blue tray appears on the production line at the start of the discharge conveyor. Otherwise, if the current tray is not acceptable, a red tray appears on the production line at the start of the reject diverter. Finally, the FIXDMACS screen displays a chart of the tray weights by time.

When the production line stops because of a system fault, the plant floor personnel must immediately know what that fault is. In addition to the "system fault" message, FIX DMACS displays the type and actual location of fault condition when a fault has occurred. The message will remain until the line is reset.

The design of the FIXDMACS display of the tray pack line is still ongoing. Several additions to the screen will be made and new screens will be added which can be accessed through a menu-driven mechanism. The computer display will show the total

uptime, total downtime, and total idle time. The idle time is defined as the time the production line is available but not running. The screen will also display the production efficiency. Production efficiency is defined as the number of acceptable seamed trays divided by the number of total trays. With access to the set point speed, production efficiency may be redefined as the number of acceptable trays divided by the total number of trays that could have been produced during the entire process time. Alarming and alarm summaries will be added to the existing screen layout. User friendly screens will be developed to enable an operator to input data. This will allow the supervisory control of the line. Finally, several different statistical charts will be added to the display.

8. Summary

In this document we have described the control strategy and implementation for the level 2 automation plan for the tray pack filling/sealing line of CRAMTD. This includes both the automation of machine control functions and the automatic acquisition of data.

Data is automatically collected from various sensors placed throughout the filling/sealing line, such as weight, mounding of material, and location of trays. The data is then presented to the operator through the use of a SCADA node and monitor. Critical information on production rates, downtime, efficiency, and material usage are all recorded and displayed.

This document is to be considered a working document. The automation software, FIX DMACS, is introduced briefly and a more detailed report on FIX DMACS implementation will follow as an update to this document.

COMBAT RATION ADVANCED MANUFACTURING TECHNOLOGY DEMONSTRATION (CRAMTD)

Material Management for Raw Material and Finished Goods: Database Design and Implementation

Technical Working Paper (TWP) 101

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1 Introduction

The Combat Rations Advanced Manufacturing Technology Demonstration (CRAMTD) project is sponsored by the United States Department of Defense (DOD), Defense Logistics Agency (DLA). The goals of the project are to create a pilot facility to demonstrate advanced manufacturing technologies which include computer integrated manufacturing (CIM). The CIM system must support the various functions of the plant including the management of materials throughout the facility.

A Materials Management (MM) subsystem tracks materials from the moment they arrive at the facility until they are shipped off to customers as finished products. Material Management goes a step beyond warehouse management by tracking materials as they flow through the production process.

Materials management in the manufacturing environment can be broken down into three distinct phases: Raw Material, In-Process and Finished Goods. These phases reflect the chronological path of materials from the time of delivery, through production and finally to the point of shipment. In this paper we focus only on the design and implementation of material management of raw material and finished goods. The tracking of materials through In-Process will be addressed in a future technical working paper.

In this paper, we will describe the underlying features of the MM subsystem. These major features include:

- *Integration* with the Purchasing and Quality Assurance (QA) subsystems.
- A *Material Hierarchy* system for relating raw materials, sub-assemblies and finished products.
- A flexible *Material Type* system for classifying materials.
- A flexible *Warehouse Locator* system for organizing the storage and movement of materials.
- A system of material *States* and *Statuses* used to track the disposition of material lots.
- A comprehensive *Material Tracking* system that logs all transactions involving material movements and usage.
- A flexible *Material Cost* system for assigning various costs to each material (e.g. storage, rework, return, testing, etc.)

Based on these underlying features, the MM subsystem supports the following major functions:

- Material and material types setup

- Warehouse and locator system setup
- Receipt of materials at delivery
- Inter- and Intra- warehouse movement of materials
- Physical inventory

2 Definitions

The following definitions pertain to the CRAMTD Materials Management subsystem and the operations of the CRAMTD food production facility.

Batch A collection of sub-assemblies or finished products produced during a given time period.

Controlled Materials Materials that require quality control testing before they can be used for production.

Delivery The arrival of materials from a supplier *to* the manufacturing facility.

Disposition The qualities that make up a material lot as recorded by the current state or status.

Location A physical area within the plant or warehouse. Examples are the Loading Dock, Freezer, Production Line, etc. The locator system is described in section 3.4 on page 12.

Material Class The APICS class for a material. The class designation determines how frequently the material should undergo a physical inventory. For example, Class A materials would be inventoried more often than Class B materials. Material classes are described in section 3.7 on page 16.

Material Lot A collection of raw material or finished products as tracked internally by the production database.

Material Lot Number A unique identifier for the material lot. This is assigned by the MM subsystem at the time of delivery or at the time of creation.

Material State The disposition of an entire material lot. Examples are *IN QC*, *RELEASED* and *REJECTED*. Material States are explained in section 3.5 on page 12.

Material Status An indication of the disposition of a material lot stored at a particular location. Examples are *QC Hold*, *On Hand* and *On Hold*. Material Statuses are explained in section 3.5 on page 12.

Material Types A series of identifiers that provide a means for classifying materials. Material Types include *RAW*, *FINISHED*, *CHOPPED*, *SLICED*, *DICED*, *WHOLE*, *BEEF*, *CHICKEN*, *PORK*, etc. Material Types are discussed in section 3.3 on page 9.

Operation A stage in the production process where one or more raw materials or sub-assemblies are transformed into finished goods or sub-assemblies.

Organization Any enterprise involved with, or related to, the CRAMTD food production facility. These include vendors, suppliers, customers, and the production facility itself.

Production Database The central plant database where all production, quality and materials management data reside.

Production Line A collection of machines used to convert raw materials into finished goods.

Shipment The movement of materials or finished products *from* the manufacturing facility to another party. Shipments can be performed to send finished goods to a customer or to return materials back to a supplier.

Warehouse A location where raw materials and finished goods are stored.

3 Underlying Features of Materials Management

In the following sections, the underlying design features of the integrated system are described.

3.1 Integration

The Materials Management (MM) subsystem is integrated with the remainder of the plant database including the Purchasing and Quality Assurance subsystems.

The Purchasing subsystem is used to generate *Requisitions* and *Purchase Orders* for new materials. A requisition can be triggered automatically when inventory levels fall below a safety stock point or when a manager wishes to order new materials.

The MM subsystem takes over when the materials arrive in a *delivery*. Each item delivered to the manufacturing facility is traced back to the originating purchase order. The quantity of material delivered is referred to as a *Material Lot* and is assigned a unique *Lot Number*.

The Quality Assurance (QA) subsystem is responsible for tracking the sampling and testing of any *controlled materials*. The QA subsystem maintains a list of samples taken from the lot and stores the results of tests performed on the samples. This information can then be used to guide quality control personnel in determining the

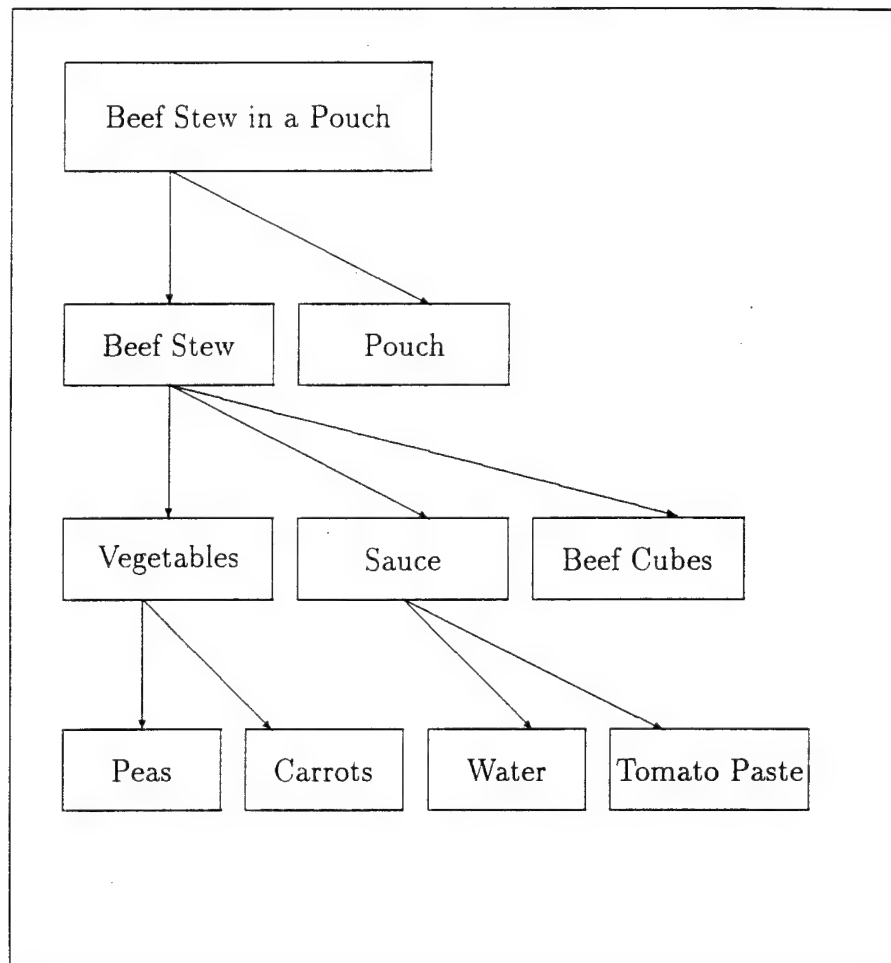


Figure 1: Parts Explosion for Beef Stew in a Pouch

disposition of the material lot. For more information on the QA subsystem, please refer to [2].

3.2 Material Hierarchy

Products in the facility are manufactured by combining various raw materials in specific quantities. It is common to refer to the *parts explosion* of a product as a means of viewing the individual components. An example parts explosion for “Beef Stew in a Pouch” is given in Figure 1.

Each level of the hierarchy represents some collection of materials that are required to make a material at the next higher level. The *raw materials* are shown at the bottom of the tree while the highest level is considered a *finished good*. The ma-

materials in the middle levels are called *sub-assemblies* or *batches*. Traditional systems store information about these various items in distinct places. This often results in confusion when referring to the items. For example, a material might be considered a sub-assembly in some cases and a raw material in other cases.

It is possible that the enterprise may wish to make all of the products from scratch meaning only raw materials such as the pouch material, water, tomato paste, carrots and peas are purchased and combined together. Another possibility is that the enterprise may purchase an intermediate set of materials such as Beef Stew and combine this with the pouch material to create a finished product. There are many variations of these situations that could also be chosen.

The CRAMTD database model uses a generalized material hierarchy to organize the relationships between materials. To generalize this structure, items at *all* levels of the hierarchy are called *Materials*. A material may have a single *parent* material and it may have zero, one or more *child* materials. In Figure 1, Beef Stew has three children: Beef Cubes, Vegetables and Sauce. Beef Stew also has a parent: Beef Stew in a Pouch. Carrots have no children but they have Vegetables as a parent.

A material structure is used to coordinate the parent-child relationship. This relationship includes additional information such as a part mixture ratio for the children and units of measure for the parent. For example, Carrots and Peas may be mixed in a 2:1 ratio in order to make Vegetables. Vegetables may then be measured in pounds. Materials may participate in many different hierarchies depending on the product being defined.

By referring to each item as a material, the enterprise has the option of purchasing materials any level, including the highest level, and in any combination, in order to manufacture finished products. This approach eliminates the confusion of having to refer to a material in a certain context such as *raw* or *sub-assembly*.

3.3 Material Types

A typical manufacturing company may require hundreds or thousands of materials in order to manufacture a wide range of products. Keeping track of such a list of parts and materials has typically been done by assigning a unique identifier to each material or part along with a longer text description. The unique identifier is often coded in such a way that the material can be deciphered by examining only its id. Such a coding scheme is shown in Figure 2.

There are three main disadvantages to this scheme:

1. Coding schemes are *closed* in the sense that each "category" is given a fixed number of places. Should the number of categories exceed these places, the coding scheme must be changed. In Figure 2, the style of preparations (i.e. Diced) are limited to 36 (26 letters and 0 - 9).
2. Once coding schemes are established, changing them can be very difficult and

Place	Meaning
1	R - Raw. S - Sub-Assembly or F - Finished goods
2	1 - Beef. 2 - Pork, 3 - Chicken. 4 - Vegetables . . .
3	1 - Whole. 2 - Diced. 3 - Sliced. 4 - Ground . . .
4-6	Three digit number for a specific material

Examples:

Diced Beef Cubes	R12001
Whole Chicken Breast	R31123
Ground, Seasoned Pork	S24981

Figure 2: A Coding Scheme for Material Identification

costly. Material identifiers are used in many other areas of the database as a link back to the materials. Therefore, any change to the identifier structure will need to be propagated throughout the system.

3. Coding schemes are difficult to decipher by humans. Although the coding scheme in Figure 2 might become easy to parse over time, longer coding schemes with additional categories may be impossible for a human reader to deconstruct.

The CRAMTD database model addresses these main criticisms, by employing a method for associating types to materials that is flexible, extensible and easy for humans to read and to understand.

Each "category" described in the Figure 2 is considered a *Material Type*. Material Types are organized into levels with the most general type at the highest level and the most specific type at the lowest level. All levels and types are given "plain English" names defined by the users of the system who are free to organize them to meet the needs of the enterprise. All material type information is stored in separate tables, not within the material tables themselves. A sample flexible coding scheme can be seen in Figure 3.

Because both the number of levels and the number of types per level are not fixed, this type method is extensible to accommodate any future changes. Since the type information is stored separately from the actual materials, changes to the material types do not affect other parts of the system. Last, because the users assign "plain English" names to the types, humans can read and understand the specifics of a material without having to learn a coding scheme. An example of the types for the material Diced Beef Cubes is given in Figure 4.

Level	Meaning
1	RAW. IN-PROCESS, FINISHED
2	BEEF. PORK. CHICKEN. VEGETABLES . . .
3	WHOLE. DICED, SLICED. GROUND . . .
4	etc.

Figure 3: A Flexible, Extensible Coding Scheme for Materials

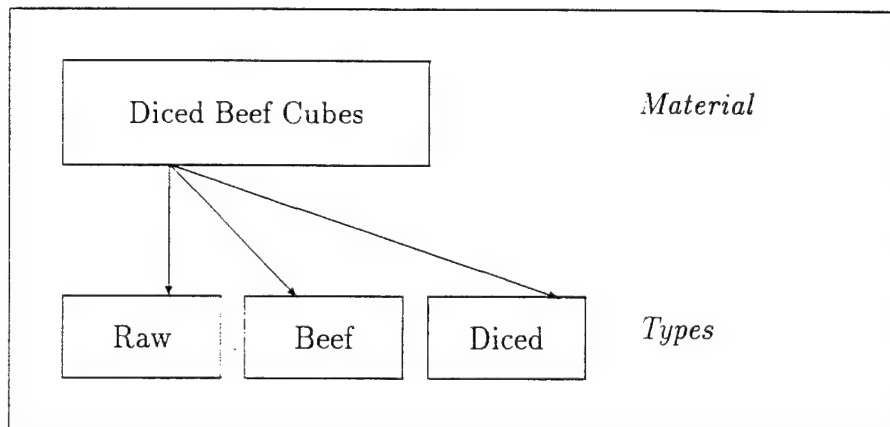


Figure 4: Flexible, Extensible Type Specification for Diced Beef Cubes

3.4 Warehouse Location

A warehouse location system is used to designate specific locations in the warehouse and elsewhere in the manufacturing facility where materials may be stored. Conventional inventory management systems lay out the entire facility as a series of *Aisles*, *Tiers* and *Bins*. Material lots may be stored by associating a quantity of material to a particular Aisle, Tier and Bin location.

It is often necessary to restrict materials to specific regions within the production facility. For example, frozen beef must be stored in the freezer and may only be moved to the production line for use. For another example, finished goods must be placed into a quarantine area until they have passed all QC tests.

Restricting materials lots to specific areas may be done via physical means such as signs posting which materials may be appropriately stored in which areas. Because such physical methods are prone to human error, most modern systems rely on rules within the inventory management subsystem to electronically prevent material storage errors.

In the CRAMTD database model, each *Organization* may have one or more *Warehouses* that can store any type of material. A *Warehouse* is broken down into user defined *Areas* that contain materials of a specific type. Within an area, the traditional Aisle, Tier, Bin designation is used to pinpoint the storage location. A sample warehouse layout can be seen in Figure 5. Materials can then be restricted to a specific area depending on material type.

3.5 Material States and Statuses

The production of food requires careful attention to the quality of materials that make up a product. Since many materials are perishable (i.e., they have a limited useable life span), it is important to maintain records of any changes made to the materials or the areas in which they are stored. A material lot (a collection of the same material) may come under a variety of conditions from the time it is manufactured until the time it is used to make another product or until it is consumed. We call the current conditions of a material lot its *disposition*.

In the CRAMTD database model, a *material lot* is defined as a quantity of material that is considered homogeneous upon delivery or creation. For example, if 10,000 pounds of beef from one supplier are delivered in one truck, the material lot would be the full 10,000 pounds. If an additional 5,000 pounds from the same supplier arrives two hours later, it would be considered as a separate material lot. After delivery, a material lot may be split up in order to store it more efficiently. In this case, the material lot is associated with a specific warehouse location called a *Material Lot Location*.

There are certain aspects of materials that apply to the entire lot while other aspects apply only to the quantity of material stored at a specific location. These aspects are given the names *States* and *Statuses* respectively.

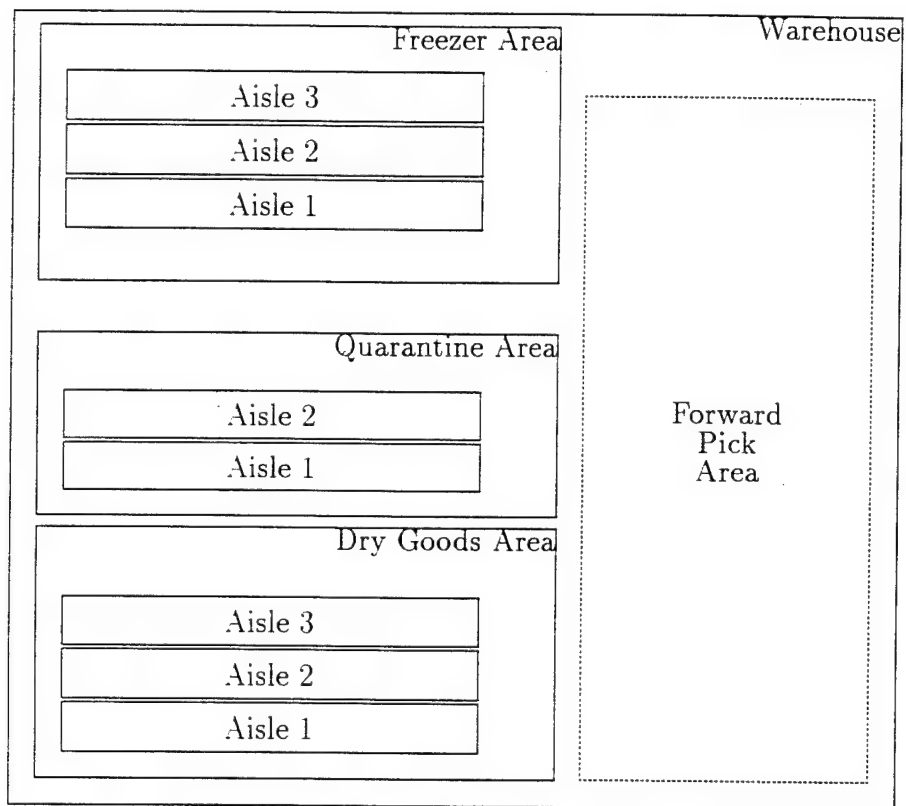


Figure 5: Sample Warehouse Layout

The material States used in the model are defined as follows:

IN QC The entire material lot is considered to be under inspection by QC personnel. Such material may not be used for any purpose nor should it be shipped to a customer.

RELEASED The entire material lot has passed QC testing and is considered to be in good condition. Such material can be used for production or can be shipped to a customer.

REJECTED The entire material lot has been tested by QC and found to be defective. Such material may not be used for any purpose. This material may be reclassified, destroyed or returned to the supplier.

Because material lots can be stored in one or more material lot locations, material *Statuses* are used to track the disposition of these parts of the complete material lot. For example, a material lot may have the state of RELEASED but a particular lot location may have spoiled or may have been damaged. The material statuses are as follows:

ON HOLD The material lot location is on hold for some reason. While in this status, the material at the location may not be used for any purpose. This status is assigned right away when any condition is suspected of compromising a material lot location.

QC HOLD The material lot location is on hold while QC tests are being performed. While in this status, the material at the location may not be used for any purpose. Typically when an entire material lot is IN QC, all of its lot locations are placed on QC HOLD.

ON HAND The material at this lot location may be used for production or shipped to a customer. Typically when a material lot is RELEASED, all of its lot location are placed ON HAND.

RECLASS The material at this lot location is marked for reclassification. While in this status, the material at the location may only be used for rework leading to a reclassification.

DESTROY The material at this lot location is marked for destruction. While in this status, the material at the location may not be used for any purpose.

RETURN The material at this location is marked for return to the supplier. While in this status, the material at the location may only be shipped as part of a Returns shipment (i.e. not as a customer shipment).

Lot State	Lot Location Status
IN QC	QC HOLD
RELEASED	ON HAND for good lot locations ON HOLD for lot locations found to be bad after release
REJECTED	ON HOLD until a decision is made RECLASS if material can be reclassified DESTROY if material is to be destroyed RETURN if material is to be returned

Figure 6: Material States and Statuses for Lots and Lot Locations

The initial state and status of *controlled* materials is IN QC and QC HOLD respectively. These conditions are what signal QC personnel to take samples and to test the material lots. Based on the test results, a material lot may be RELEASED in which case all lot locations statuses become ON HAND, or it may be REJECTED, in which case all lot locations statuses will change to ON HOLD. Once ON HOLD, the status may then change to RETURN, DESTROY or REWORK depending on the arrangements made by purchasing and the supplier. These states and statuses are compared in Figure 6. For more information on the quality control aspects of the CRAMTD database model please consult [2].

3.6 Material Auditing

Many food products contain ingredients that may be very costly and, hence, require careful attention to the quantities used and wasted before and during production. The material auditing function of the CRAMTD database uses a *double entry* method for recording material transactions. Such transactions may include:

- Creating a quantity of material in a new material lot.
- Moving a quantity of material from one location to another.
- Shipping a quantity of material to a customer.
- Destroying a quantity of material.
- Adjusting the state of a material lot.
- Adjusting the status of a material lot location.

Three mechanisms exist in the CRAMTD database model to track these transactions “behind the scenes”. In each case, the date and time the transaction occurred as well as the user id of the person responsible for the transaction are recorded. These mechanisms are described as follows:

Material Audit Trails Any creation, destruction or movement of materials creates a material audit trail record. This record indicates the type of transaction taking place and should be balanced by a matching transaction in the future. For example, moving a material lot requires two transactions, a "quantity Debit" from one location and a "quantity Credit" in another location.

Material State Logs Any transaction that involves a change of material lot state is recorded in the material state logs. The "From state" and "To State" are recorded along with the material lot number, date and time and the user id.

Material Status Logs Any transaction that involves a change of material lot location status is recorded in the material status logs. The "From status" and "To Status" are recorded along with the material lot number, location, date and time and the user id.

Listing the audit trails for a given material lot gives a complete history of everything that happened to the lot during its lifetime at the CRAMTD facility.

3.7 Material Classes

Any manufacturing facility has on hand, a variety of raw materials that differ in value. Materials that are very expensive or prone to shrinkage should be inventoried more frequently than less expensive materials. Material classes can be set up to simplify the scheduling of physical inventories done on raw materials and finished goods.

A well known example of material classification is the APICS classes. This scheme breaks materials down into three classes, **A**, **B** and **C**. Class A materials are the most valuable and are therefore placed under close scrutiny. Class C materials are at the other end of the spectrum and can be accounted for less frequently. Class B materials fall between A and C.

As an example, consider a company that makes beef stew MREs. The following chart gives an ingredients listing with the APICS class assigned to each material and the frequency of physical inventory:

Material/Ingredient	APICS Class	Inventory
Raw Beef	A	Every 2 Months
Mixed Vegetables	B	Every 6 Months
Tomato Paste	B	Every 6 Months
Water	C	Every 12 Months
Spices	C	Every 12 Months
Pouch/Webbing Material	C	Every 12 Months

Note that this assignment will differ depending on the organization implementing the material classes. In some organizations where shrinkage presents a severe problem,

inventory frequency can be increased and more materials would be considered in the A or B class.

The database model for material classes affords flexibility in the number of classes designated (virtually unlimited) and the ability to assign a different inventory frequency for each class.

3.8 Material Costs

A variety of costs are associated with the manufacture or purchase of a material or product. These costs are used by an accounting department to make business decisions such as whether to manufacture a new product.

In the CRAMTD database model, several *Material Costs* can be associated with each material. They are:

Raw Material Cost The cost for the basic raw materials.

Labor Cost The labor costs involved in making the product.

Overhead The overhead costs associated with supporting the manufacture or purchase of a product.

Miscellaneous Any costs not fitting in the above categories.

This set of costs will be different depending on if the goal is to purchase a new material, make a new material or reclassify an old material into a new material by *reworking* it. Each one of these is referred to as a *Material Cost Type*. Some examples are:

Purchase The costs to purchase the material or product.

Manufacture The costs to manufacture a material or product.

Rework The costs to rework a material into a new material.

4 Database Design

The information systems of an organization are made up of a set of activities that regulates the sharing and distribution of information and the storage of data that are of relevance to the operation and management of the organization.

A proper design of the underlying database of an information system of an organization must therefore be based on the understanding of the system's activities and their information requirements. Below is a discussion of our model of the system's activities followed by a discussion of the corresponding data model.

4.1 The Functional Model

The functional analysis has been performed by a top-down, structured, systems analysis technique called IDEF0 [6, 7, 8]. The IDEF0 model of the CRAMTD application is described in [3]. The IDEF0 technique models a system's activities and the information flow among them. To construct an IDEF0 model, we initially represent the generic activities of the system and then successively decompose each of these activities into greater detail. The building blocks of the IDEF0 model are:

- The activity (function) box: This represents an activity or function of a system. This could be either a generic activity or one of the detailed activities that constitute a generic activity.
- Arcs: These represent inflow and outflow associated with a given function box. There are four types of arcs:
 - Input: Represents the set of inputs, e.g., information and materials required to perform the activity. This is depicted by an arrow entering the activity box from the left.
 - Output: Represents the outflow from the activity. This is depicted by an arrow leaving the activity box from the right.
 - Control: Represents the constraints that govern the process by which the activity is performed. This is depicted by an arrow entering the activity box from the top.
 - Mechanism: Represents the human or equipment resources that are required in performing the activity. This is depicted by an arrow entering the activity box from the bottom.

More than 100 activities are identified in the target application area. For more details about the functional model of the CRAMTD application, please see [3].

4.2 The Data Model

The technique used for data modeling is known as IDEF1X, a semantic data model based on Codd's relational data model [5] and Chen's entity-relationship model [4]. An entity is an element of the system that is relevant to the Material Management operation. An entity could be something tangible such as a receiving clerk or something more abstract such as an adjustment reason code. Each entity is described in terms of one or more attributes. The real life interaction between one entity and another is represented in the Entity-Relationship (E-R) model by a relationship. A diagram of these entities and their relationships is known as an E-R diagram. The IDEF1 model is used to develop the conceptual schema of the application. The building blocks of the IDEF1X model are entities, attributes, and relationships.

The IDEF1X model for our target application is described in more detail in [1].

Entities are represented by boxes in the IDEF1X model. Identifier-dependent (ID) entities, which are child entities whose existence depends on that of the parent entity, are shown by boxes with round corners. Identifier-independent (II) entities have independent existence, and are shown with boxes with square corners.

Attributes of an entity are listed inside the entity box. The primary key attributes are listed above a horizontal line inside the entity box. ID entities *inherit* the primary key attributes of their parent entities. Multiple inheritance is allowed in this data model.

Relationships are represented by arcs in the IDEF1X model. If one of the entities connected by an arc is child entity, then the arc is represented by a bold line. The dot at the end of an arc identifies the child entity. Arcs connecting two entities that do not have a parent-child relationship are represented by a dashed line. Relationships are named by verb phrases. In addition, a fully developed IDEF1X model replaces each m:n relationship with an additional cross reference entity and two 1:n relationships.

4.3 The CASE Model

Using Oracle Computer Aided Software Engineering (CASE) tools, specifically Oracle CASE*Dictionary and Oracle CASE*Designer, the user requirements were translated into a single function hierarchy that shows all the relevant activities. The IDEF0 model introduced in the previous section was used as a starting point to develop a functional hierarchy that is integrated with the E-R model.

In a functional hierarchy, the higher level, generalized functions are at the top and more detailed functions are shown at the end of the paper (see Appendix I). The leaf nodes in the hierarchy are elementary functions that may become actual data entry or reporting screens.

Each of these activities are further defined, based on the entity relationship model (E-R), in terms of the entities, attributes, and the relationships they use. The Material Management application requires the use of over 31 elementary functions. Some of

these are described in the *Function to Entity Matrix* report shown in Appendix II. An example matrix for the *Warehouse Data Entry* function is given below.

- **Function : M0.1**

Definition: Warehouse Data Entry

Entity	Create	Retrieve	Update	Delete
WAREHOUSE	Y	Y	Y	Y

The model defined in the Oracle*CASE tool reflects the rules of the business as described by the personnel at the CRAMTD food production facility. The business rules can be captured as relationships between entities, additional attributes for an entity or the use of an entity by a particular function. The Oracle CASE*Designer provides an E-R diagramming function as shown in Appendix III.

Entities and their definitions can be seen in the *Entity Definition Report* provided by CASE*Dictionary. A full *Entity Definition* report for the Material Management application is shown in Appendix IV. As an example, the definition for the Warehouse entity is shown below.

- **WAREHOUSE**

A warehouse is a place where materials can be stored.

Entities are related to one another by relationships. The Oracle CASE tools allow the designers and analysts to designate meaningful sentences for each relationship that reflects the *business rules* of the enterprise.

Each relationship has two participating entities at each end. The entities are designated by their names as shown in the previous figure. The participation in the relationship can be either *mandatory* or *optional* and is indicated by the phrases "MUST BE" and "MAY BE" respectively. Relationships also have cardinality as expressed by the phrases "ONE AND ONLY ONE" and "ONE OR MORE".

As an example, several relationships for the Material entity are shown below:

- Each **material** may be accounted for according to one or more **material costs**
- Each **material** may be the material making up one or more **material lots**
- Each **material** may be cross referenced to a warehouse in one or more **material warehouses**
- Each **material** may be purchased on one or more **purchase order items**

- Each **material** may be related to one or more **material type cross references**
- Each **material** may be requisitioned by one or more **requisition details**
- Each **material** may be restricted to one or more **area materials restricted**

A full listing of relationships for the materials management subsystem is given in Appendix V.

5 Database Implementation

The implementation of the material management portion was done using a third Oracle product, the CASE*Generator. This tool takes the function to entity matrix and constructs data entry forms and reports that are bound together by menus. In general, the CASE*Generator can handle complex user requirements and business rules.

To standardize the custom coding process, a code review was performed to identify common sections of code that could be generalized and shared between several data entry screens. Such code can be placed into "Packaged Procedures" and automatically included in each form via the CASE*Generator.

The final system is implemented on a local area network using a combination file and database server serving client machines. Server and client machines are connected over the building-wide ethernet network using the Novell Netware IPX/SPX protocol. The server runs Oracle Database Server for Netware and client machines run the Oracle tools suite; SQL*Forms, SQL*ReportWriter, SQL*Menu and SQL*Plus.

6 Material Management Database Menu Options

Warehouse personnel will be presented with a pull-down menu. The menu items and the associated submenus are shown in Figures 7 through 15.

7 Material Management Database Screens

The database screens for the Material Management subsystem are shown in Figures 16 through 45.

8 Major Functions of Materials Management

The design and implementation tools described in the previous section were used to create the Materials Management subsystem's menus, data entry screens and reports. In this section, the major functions of the Materials Management subsystem are described based on the underlying features introduced in section 3. The data entry screens and menus are shown in figures and are referenced in the descriptions.

8.1 Reference Data

The Material Management subsystem has an extremely flexible design that allows many attributes of the system to be customized as per the requirements of a given organization. This customization is accomplished predominantly by setting reference data items that are later used throughout the system. Reference data must be set up and entered into the system before performing any other functions.

Reference data that can be customized are as follows:

Material Types Material Types (see section 3.3) for each level of the material type hierarchy must be agreed upon and entered. This screen is shown in Figures 16 and 17 on pages 31 and 32.

Material Cost Types Each material can have several cost types associated with it (see section 3.8). The material cost types to be used in the system must be designated before materials are created. This screen is shown in Figure 18 on page 33.

Material Class The material classes that will be used to determine the inventory frequency (see section 3.7) must be entered. This screen is shown in Figure 19 on page 34.

Area Types Areas within a warehouse may be designated to store materials of certain type. The warehouse area types (see section 3.4) must be designated prior to setting up the warehouse locator system. This screen is shown in Figure 20 on page 34.

Material States The material states to be used for entire material lots (see section 3.5) must be designated before creating any material lots. This screen is shown in Figure 21 on page 35.

Material Status The material statuses to be used for material lot locations (see section 3.5) must be designated before storing material lots in a warehouse location. This screen is shown in Figure 22 on page 35.

Status Combinations Material statuses may only change as prescribed by predefined rules. A rule is expressed as a combination of a "From Status" and a

"To Status" that indicates valid changes to the status of a material lot location. Status combinations must be designated before any material lot locations change status. This screen is shown in Figure 23 on page 36.

Material Transaction Types Materials may be manipulated as per predefined transactions (see section 3.6). The types of transactions, such as *withdraw from inventory* must be designated. This screen is shown in Figure 24 on page 36.

Adjustment Codes After a physical inventory has been completed, it is often necessary to adjust actual inventory levels in the database. Adjustment codes can be designated for each type of adjustment and relate this to a reason for adjustment. This screen is shown in Figure 25 on page 37.

Shipment Types Shipments from the organization can be done for a number of reasons. Each shipment has a shipment type associated with it indicating the purpose of the shipment. Some examples are:

Shipment Type	Reason
ORDER	To fill a customer order
RETURN	To return materials to the supplier
TRANSFER	To transfer materials between warehouses

The screen for Shipment Type Data Entry is shown in Figure 26 on page 37.

8.2 Material Setup

Once all of the reference data has been entered into the system, the material records that will be tracked using the database must be created in the system. Material Setup uses two data entry screens (or simply, screens) to accomplish this. The first screen is used to create a unique Material Identifier and to assign the material types. The second screen is used to assign cost types to the material for accounting purposes. These screens are shown in Figures 27 and 28 starting on page 38.

8.3 Warehouse Setup

Warehouses and the layout of their contents can be created using the screens shown in Figure 29 on page 40. Each warehouse is given a unique identifier. Area Types are assigned to areas within the warehouse. Each area is then broken down into Aisle, Tier and Bin locations. Each bin has specific dimensions and has an associated maximum load weight.

8.4 Delivery of Materials

Materials that are delivered to the plant are matched against outstanding purchase orders and additional information about the delivery event is recorded. If the delivery is accepted, material lots are then created from the delivered materials. The screen to accomplish these actions is shown in Figure 30 on page 41.

8.5 Material Movement

Materials can be moved between warehouses and within warehouses. Movement within a warehouse is done using the Material Movement screen shown in Figure 38 on page 49. Any material lot can be queried and all of the material lot locations for that lot are displayed. Once a new location has been reached, the location codes (warehouse, area, aisle, tier, bin) can be entered to complete the move. Bar code scanners are used to scan in the lot numbers and location codes to reduce data entry errors.

8.6 Lot Maintenance

From the time a material lot is created at the plant, several modifications may need to be done to the lot and its lot locations where it is stored. One common activity is the need to change a lot's state or a lot location's status. For example, if an inspector finds some contamination in a warehouse location, all of the lots stored in that location should be placed "ON-HOLD" as soon as possible. The screen to change a lot's state is shown in Figure 33 on page 44 and the screen used to change a lot location's status is shown in Figure 34 on page 45. A log of all status changes is maintained and can be seen in Figure 36 on page 47.

8.7 Physical Inventory

Physical inventory is done in three steps. First, the cycle counts (based on Material Class) for materials in the warehouse are examined to determine when an inventory should be done and on what materials it should be done. This screen is shown in Figure 39 on page 50. Second, an inventory report is printed showing the materials and the lot locations to be inventoried. The quantity fields are left blank. Employees performing the inventory fill in the physical inventory counts for each lot location. The last step is to compare the physical inventory to the database records and adjust the inventory levels as needed. This function can be performed using the screen in Figure 32 shown on page 43.

It is also possible that materials in a lot location may be found to be damaged. In this case, the Status Change screen shown in Figure 34 on page 45 would be used to place the lot location "ON HOLD" until a decision can be made to either rework the material or destroy it.

8.8 Material Lot Destruction

When material lots have spoiled or have been rejected by quality control, they may be destroyed. The destruction of materials must be controlled and the methods used for the destruction must be recorded. The screen to accomplish this is shown in Figure 37 on page 48.

8.9 Inquiry

The Material Management subsystem also contains several query-only screens that offer a high level view of materials controlled by the organization. These Inquiry screens are shown in Figures 40 through 45 on pages 51 through 56.

```

Materials Quality Production Purchasing Maintenance Exit
----- C R A M T D -----

```

Figure 7: The Main Menu of the C R A M T D Application Database

```

Materials  Quality  Production  Purchasing  Maintenance  Exit
-----+----- C R A M T D -----
| Reference      > |
| Material Setup > |
| Location Setup > |
| Lot Maintain   > |
| Inv Movement   > |
| Phy Inventory  > |
| Inquiry        > |
| Reports        > |
+-----+

```

Figure 8: The Materials Management Menu

Materials	Quality	Production	Purchasing	Maintenance	Exit
-----+-----+-----					
Reference	>>	Material Type			
Material Setup	>	Cost Type			
Location Setup	>	Material Class			
Lot Maintain	>	Area Types			
Inv Movement	>	Material States			
Phy Inventory	>	Material Status			
Inquiry	>	Status Comb.			
Reports	>	Transact Type			
+-----		Adjust Codes			
		Ship Type			
		-----+			

Figure 9: Materials Management - Reference Submenu

Materials	Quality	Production	Purchasing	Maintenance	Exit
			CRAMTD		
-----+-----					
Reference	>	+-----+			
Material Setup	>>	Materials			
Location Setup	>	Materials Cost			
Lot Maintain	>	Type CrossRef			
Inv Movement	>	+-----+			
Phy Inventory	>				
Inquiry	>				
Reports	>				
+-----+					

Figure 10: Materials Management - Material Setup Submenu

Materials	Quality	Production	Purchasing	Maintenance	Exit
-----+-----		CRAMTD	-----		
Reference	>				
Material Setup	> +-----+				
Location Setup	>> Organizations				
Lot Maintain	> Ware/Area/Loc				
Inv Movement	> +-----+				
Phy Inventory	>				
Inquiry	>				
Reports	>				
+-----+					

Figure 11: Materials Management - Location Setup Submenu

```

Materials  Quality  Production  Purchasing  Maintenance  Exit
-----+----- CRAMTD -----
| Reference      > |
| Material Setup > |
| Location Setup > +-----+
| Lot Maintain   >>| Lot Receipt   |
| Inv Movement   > | Lot Adjustment |
| Phy Inventory   > | State Change  |
| Inquiry         > | Status Change  |
| Reports        > | Lot Return     |
+-----+-----| Status History |
                  | Lot Destructio |
                  | Create a Lot   |
                  +-----+

```

Figure 12: Materials Management - Lot Maintain Submenu

```

Materials  Quality  Production  Purchasing  Maintenance  Exit
-----+----- CRAMTD -----
| Reference      > |
| Material Setup > |
| Location Setup > |
| Lot Maintain   > +-----+
| Inv Movement   >>| Location Move  |
| Phy Inventory   > | Inter WH Move  |
| Inquiry         > +-----+
| Reports        > |
+-----+-----+

```

Figure 13: Materials Management - Inventory Movement Submenu

Materials	Quality	Production	Purchasing	Maintenance	Exit
-----+----- CRAMTD -----					
Reference	>				
Material Setup	>				
Location Setup	>				
Lot Maintain	>				
Inv Movement	>	+	-----+		
Phy Inventory	>>		Cycle Info.		
Inquiry	>		Inv. Report		
Reports	>		Reconciliation		
+	-----		Mat Requisition		
		+	-----+		

Figure 14: Materials Management - Physical Inventory Submenu

Materials	Quality	Production	Purchasing	Maintenance	Exit
-----+----- CRAMTD -----					
Reference	>				
Material Setup	>				
Location Setup	>				
Lot Maintain	>				
Inv Movement	>				
Phy Inventory	>	+	-----+		
Inquiry	>>		Material Inq.		
Reports	>		Warehouse Inq.		
+	-----		Lot Inquiry		
			Lot/Mat Inq.		
			Location Inq.		
			Mat/WH Scan		
			Lot/Loc Scan		
		+	-----+		

Figure 15: Materials Management - Inquiry Submenu

Page 1 of 1
Date 29-JUL-94

Type	Description
BEEF	Materials made out of beef
DICED	DICE MATERIAL
FINISHED	FINISHED GOODS
RAW	RAW MATERIAL

31

User OPS\$USER Material Type Cross References Page 1 of 1
Date 29-JUL-94

+-- Material Type Cross Reference -----+	
Material Type ID	Material ID
RAW	1
RAW	6
BEEF	1
BEEF	6
RAW	3
RAW	2
BEEF	2
RAW	10
DICED	15
BEEF	10
FINISHED	3
BEEF	15
FINISHED	14
+-----+	

Figure 17: Materials | Material Setup | Material and Material Type Cross Reference

User OPS\$USER

Material Cost Type

Page 1 of 1

Date Fri,29-JUL

Material Cost Types	
Cost Type	Description
MANUFACTURE	The costs of manufacturing this
PURCHASE	The costs associated with purc

Figure 18: Materials | Reference | Cost Type Data Entry Screen

User OPS\$USER Material Class Data Entry Form Page 1 of 1
Date 29-jul-94

+-- Material Classes -----+			
	Classification	Cycle Time	Cycle Time Units Class Descrip.
	A		APICS Class A
	B		APICS Class B
	C		APICS Class C
+-----+			

Figure 19: Materials | Reference | Material Class Data Entry Screen

User OPS\$USER Area Type Data Entry Page 1 of 1
Date 29-JUL-94

+-- Area Types -----+		
	Area Type Id	Description
	FROZEN	Freezer Area
	DRY	Dry storage
	DOCK	Loading dock
	REFRIGER	Refrigerated Area
+-----+		

Figure 20: Materials | Reference | Area Types Data Entry Screen

```

User OPS$USER          Material States          Page 1 of 1
                                          Date 29-JUL-94
+-- Material States -----+
|
|          State          Description          |
|          IN QC          IN QC....          |
|          REJECTED       Rejected material lot |
|          RELEASED       Released into production |
|
|
|
|
|
|
+-----+

```

Figure 21: Materials | Reference | Material States Data Entry Screen

```

User OPS$USER          Material Status List      Page 1 of 1
                                          Date 29-JUL-94
+-- Material Statuses -----+
|
|  Status      Description      Qty Affected      |
|  ON HOLD     Hold for some reasons      |
|  RELEASED    Released to production      QUANTITY_IN_QC |
|  SPOILED     Spoiled at some reason      |
|
|
|
|
|
|
+-----+

```

Figure 22: Materials | Reference | Material Status Data Entry Screen

User OPS\$USER Material Status Combinations Page 1 of 1
Date 29-JUL-94

Material Status Combinations	
From Status	To Status
ON HOLD	RELEASED
ON HOLD	SPOILED
RELEASED	SPOILED

Figure 23: Materials | Reference | Status Combinations Data Entry Screen

User OPS\$USER Material Transaction Types Page 1 of 1
Date 29-JUL-94

Material Transaction Types	
Type	Description
A+	ADJUSTMENT INCREASE
A-	ADJUSTMENT DECREASE
CR	MATERIAL LOT CREATION
M+	MOVEMENT TO THIS LOCATION
M-	MOVEMENT FROM THIS LOCATION

Figure 24: Materials | Reference | Transaction Type Data Entry Screen

Reason Code	Description	Acct No.	Sign
CREATE LOT	lot creation		
RELOCATION	Relocate lot to new location(s)		

```

User OPS$USER                               Shipment Types                               Page 1 of 1
                                              Date 29-JUL-94

+-- Shipment Types -----+
|
|      Type      Description
|      ORDER     Shipment of a customer order.
|      RETURN     A return of bad goods.
|      TRANSFER   Transfer to another warehouse.
|
|
|
|
|
|
+-----+

```

User OPS\$USER Create and Maintain Material Page 1 of 1
Date 29-JUL-94

+-- Materials -----+									
Material Id	Type1	Type2	Type3	Type4					
10	RAW	BEEF							
Controlled Description	Lifespan		Lifespan U.		Order U.				
N	Precooked beef knuc 90		DAYS		LB.				
Storage Mfg.	Mfg.	Purch.	Purchasing	Last					
UOM	LeadTime	LeadTime U.	LeadTime	LeadTime U.	Purchased				
LB.	0		30		01-SEP-93				
+-- Restricted Areas -----+									
Description									
Freezer Area									
Refrigerated Area									
+-----+									

Figure 27: Materials | Material Setup | Materials, Material Types, Restricted Areas

User OPS\$USER

Material Cost

Page 1 of 1

Date 29-JUL-94

```
+-- Materials -----+
|
| Material:10   Type1:RAW   Type2:BEEF   Type3:   Type4:   |
|
+-- Material Costs -----+
|
| Type: PURCHASE   Cost Desc.: The costs associated
|
| Material Cost:           Overhead 1:           Overhead 2:
|
| Misc:           Misc 2:           Misc 3:           Total:
|
+-----+
```

Figure 28: Materials | Material Setup | Material Cost Association

User OPS\$USER Create and Maintain Warehouses Page 1 of 2
Date 04-AUG-94
-AQ-

```

+--- Warehouses -----+
|
| Warehouse Id: 1    Name: Food Plant Warehouse Loc: 1    Org: 1 |
|
| Address: 120 New England Ave.    City: Piscataway    ST: NJ |
|
| Country: USA |
|
+--- Warehouse Areas -----+
|
| Area Id    Area Type    Area Type Description    Rest. Area |
| DOCK       DRY        Dry storage                N |
| DRYS       DRY        Dry storage                N |
|
+--- Warehouse Bin Locations -----+
+-----+

```

User OPS\$USER Create and Maintain Warehouses Page 2 of 2
Date 04-AUG-94

```

+--- Warehouses -----+
|
| Warehouse Id: 1            Name: Food Plant Warehouse |
|
+--- Warehouse Areas -----+
|
| Area Id: DOCK |
|
+--- Warehouse Bin Locations -----+
|
| Aisle: 1    Bin: 1    Tier: 1    Loc. Type: QUANANTEENED |
|
| Bin Size: VERY LARGE            Load Limit:            Stackable: Y |
|
| Height: 20                      Depth: 20            Bin Width: 20 |
|
+-----+

```

Figure 29: Materials | Location Setup | Warehouse Locations Data Entry

User OPS\$USER Verify PO and Create Delivery Details Page 1 of 1
Date 27-AUG-94
-AQ-

```

+--- Deliveries -----+
| Del. Id.   Clerk Id.   Carrier           Date/Time       |
| 10         1          JOE'S TRUCKING    27-AUG-94 15:03 |
|                                                    |
| Driver     Vehicle Condition   Temperature   Comments      |
| JOE        Good              50              none       |
|                                                    |
+--- Delivery Details -----+
|                PO      PO      Item              |
| Item   PO NO.   Line Item Status   Crt. Status   Comments      |
| 1      2        1      OP          N      A          Good      |
|                                                    |
| Lot No.   Mat. Id. Type1  Type2  Type3   Type4   Qty   UOM |
| 56        1      RAW    BEEF                500   lb.  |
|                                                    |
+--- Material Lots -----+
| Create Date Time   Create Qty   VLot NO.   VLot Prod. Date |
| 27-AUG-1994 15:42   0           VL14-A09   01-AUG-94      |
+-----+

```

Figure 30: Materials | Lot Maintain | Create Delivery

User OPS\$USER

Create a New Material Lot

Page 1 of 2

Date 04-AUG-94

```
+--- Material Lots -----+
|
|      Lot Number: 78                Material Id: 1  |
|
|      Description: Reformed Beef Cubes          Org. Id: 1  |
|
|      Name: CRAMTD FOOD TECHNOLO  Create Date: 11-JUL-94 |
|
|      Create Qty: 70                Contract Number:      |
|
|      Vend. Lot Num: 23322          |
|
|      Vend. Lot Prod. Date:          Qty Rejected:0       |
|
|      Qty In QC: 70                Qty On Hand: 0         |
|
+--- Material State Logs ----- Continued ---+
+--- Material Lot Locations -----++
```

User OPS\$USER

Create a New Material Lot

Page 2 of 2

Date 04-AUG-94

```
+--- Material State Logs -----+
|
|      Mat. State: IN QC  Last Changed: 11-JUL-94  Person Id: 1 |
|
+--- Material Lot Locations -----++
|
|      Mat. Status: ON HOLD      Quantity: 70          |
|
|      Qty Reserved: 0                Warehouse Id: 1    |
|
|      Area Id: DOCK              Aisle: 1             Tier: 1  |
|
|      Bin: 1                      |
|
+-----+
```

Figure 31: Materials | Lot Maintain | Create a Lot

User OPS\$USER

Inventory Adjustment

Page 1 of 2

Date 04-AUG-94

-AQ-

+--- Material Lots -----+									
	Mat. Id.	Type1	Type2	Type3	Type4	Lot No.			
	1	RAW	BEEF			60			
+--- Material At Warehouse Bin Locations -----+									
	Mat. Status	Warehse	Area	Aisle	Tier	Bin	Qty	Reason	Adj. Qty
	ON HOLD	1	FREZ	2	1	1	100	ADJUST-	0
	ON HOLD	1	DRYS	1	1	4	100	ADJUST-	0
	ON HOLD	1	FREZ	2	1	5	300	ADJUST-	0
	ON HOLD	1	FREZ	1	1	5	100	ADJUST-	0
+-----+									

Figure 32: Materials | Lot Maintain | Lot Adjustment

Page 1 of 1
Date 04-AUG-94
-AQ-

```
+-- Material Lots -----
```

	Material	Create
Lot No	Id Type1 Type2 Type3 Type4	Date Time
73	6 RAW BEEF	13-JAN-94 13:44

```
+-- Material State Logs -----
```

Mat. State	Last Changed	Person Id
IN QC	13-JAN-94	1
REJECTED	13-JUN-94	1

44

User OPS\$USER

Artificial Status Change

Page 1 of 1
Date 04-AUG-94

-AQ-

```
+--- Material Lots -----+
|
| Material:6      Type1:RAW      Type2:BEEF  Type3:      Type4:      |
|
| Lot No.: 73   Create Date Time: 13-JAN-94   Create Qty: 200   |
|
+--- Material Lot Locations -----+
|
| Warehouse Id  Area Id  Aisle  Tier  Bin  Quantity  New Status |
| 1             DOCK    1      1    1    200      SPOILED   |
|
|
|
|
+-----+
```

Figure 34: Materials | Lot Maintain | Lot Adjustment

User OPS\$USER

Schedule Return Shipment

Page 1 of 1
Date 04-AUG-94

-AQ-

```
+-- Returns -----+
|
|   Return Id: 1      Sched. Date Time: 11-JUL-94 15:27:26
|
+-- Return Details -----+
|
| Ret.
| Item  Lot No.  Material Id.   Type1   Type2   Type3   Type4
|  1      61      1             RAW     BEEF
|
|   Return Qty  Qty Unit   Vlot No.   Vendor Prod. Date
|   500         LB.       VL123       02-NOV-93
|
|   Return Authorization Number: 12345678
+-----+
```

Figure 35: Materials | Lot Maintain | Lot Return

```

User OPS$USER                Material Status Log Query      Page 1 of 1
                             For Material Lots              Date 04-AUG-94
+--- Material Lots -----+
|
| Lot No.  Material Id Type1  Type2  Type3  Type4 Create Date/Time|
| 73        6          RAW    BEEF                13-JAN-94 13:44 |
|
|
+--- Material Status Logs -----+
|
| Status      Whouse  Area  Aisle  Tier  Bin  Person Id  Changed |
| ON HOLD     1       DOCK  1      1    1    1          13-JAN-94|
| SPOILED     1       DOCK  1      1    1    1          20-JUL-94|
|
|
+-----+

```

Figure 36: Materials | Lot Maintain | Status History

User OPS\$USER

Record Destruction Events

Page 1 of 1
Date 27-MAR-94

-AQ-

```
+-- Destruction Logs -----+
|
| Dest. Id: 1      Supervisor Id: 1      Last Name: Cramtd user |
|
| Dest. Date: 10-OCT-94      Method: Lye |
|
| Reason:   Spoiled |
|
| Comments: None |
|
+-- Destruction Detail Items -----+
|
|      Lot      Material  Create      Qty. |
| Item Number Id      Qty.  Description  Destroyed UOM |
| 1      50      1      500    Reformed Beef Cubes  500    LB. |
|
|
|
+-----+
```

Figure 37: Materials | Lot Maintain | Lot Destruction

User OPS\$USER

Generic Material Movement

Page 1 of 1
Date 04-AUG-94

```
+-- Material Lots -----+
|
| Mat. Id.   Type1      Type2      Type3      Type4      Lot No. |
|  6         RAW       BEEF                73      |
|
+-- Quantities At Material Lot Location -----+
|
| Whouse Area  Aisle Tier  Bin   Status      Quantity |
|  1      DOCK  1      1    1     SPOILED      200      |
|
+-- DESTINATION Material Lot Locations -----+
|
| Whouse Id:  1      Area: DOCK  Aisle:1  Tier:1  Bin:1 |
|
| Loc. Type: QUANANTEEN  Bin Size: VERY LARGE Mat. Status: SPOILED |
|
| Qty:  200                      Qty_Reserved:  0      |
|
+-----+
```

Figure 38: Materials | Inventory Movement | Location Move

```

\begin{figure}
\begin{verbatim}
User OPS$USER      Review Cycle Time For Materials      Page 1 of 1
                                                           Date 04-AUG-94

+-- Materials -----+
|
| Material Id      Type1      Type2      Type3      Type4      |
| 1                RAW        BEEF                                     |
|
|
+-- Material Warehouses -----+
|
| Warehouse Id: 1      Wareh. Name: Food Plant Warehouse |
|
| Mat. Classification:      Class Descrip.:      |
|
| Qty On Hand: 0                Last Cycle Date:      |
|
+-----+

```

Figure 39: Materials | Physical Inventory | Cycle Information Data Entry

User OPS\$USER

Material Inquiry

Page 1 of 1
Date 04-AUG-94

```
+--- Materials -----+
|
| Material:1      Type1:RAW   Type2:BEEF   Type3:      Type4: |
|
| Demand Qty:                Backorder:                On Order: |
|
| Planned:                Short:                Transit: |
|
| Reserved:                Qty In QC: 500                Destroyed: |
|
| Rejected:                On Hold:                Spoiled: |
|
| Yr. Adjust.:                Yr. Issues:                Yr. Receipts: |
|
+-----+
```

Figure 40: Materials | Inquiry | Material Inquiry

User OPS\$USER

Warehouse Inquiry

Page 1 of 1
Date 04-AUG-94

```
+-- Warehouses -----+
|
|      Id: 1              Name: Food Plant Warehouse      |
|
+-- Material Warehouses -----+
|
| Material:1      Type1:RAW      Type2:BEEF      Type3:      Type4: |
|
| On Hand: 0              Backordered: 0              On Order: 0 |
|
| Planned: 0              Short: 0              Transit: 0 |
|
| Reserved: 0              Qty In QC: 500              Destroyed: 0 |
|
| Rejected: 0              On Hold: 0              Spoiled: 0 |
|
| Yr. Adjust.: 0              Yr. Issues: 0              Yr. Receipts: 0 |
|
+-----+
```

Figure 41: Materials | Inquiry | Warehouse Inquiry

+--- Material Lots -----							
Lot No	Material	Id	Type1	Type2	Type3	Type4	Description
73	6		RAW	BEEF			Precooked Diced
Lifespan	Lifespan	U.	Total	On Hand	Create	DateTime	Create Qty
90	DAYS				13-JAN-94	13:44	200
VLot No		VLot	Prod.Date		Qty In QC		Qty On Hand
12345567			12-JAN-94		200		
+--- Material Lot Locations -----							
Warehouse Id	Area Id	Aisle	Tier	Bin	Quantity	Mat.	Status
1	DOCK	1	1	1	200		SPOILED

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```

User OPS$USER                Location Inquiry                Page 1 of 1
                                                                Date 04-AUG-94
+-- Materials -----+
|
| MaterialL:1      Type1:RAW    Type2:BEEF   Type3:    Type4:    |
|
+-- Material Lots -----+
|
|                      Lot Number: 60
|
+-- Material Lot Locations -----+
|
| Mat. Status   Quantity   Warehouse   Area   Aisle   Bin   Tier   |
| ON HOLD       100         1           FREZ   2     1     1     |
| ON HOLD       100         1           DRYZ   1     4     1     |
| ON HOLD       300         1           FREZ   2     5     1     |
| ON HOLD       100         1           FREZ   1     5     1     |
|
+-----+

```

Figure 43: Materials | Inquiry | Location Inquiry

Materials			
Material:1	Type1:RAW	Type2:BEEF	Type3: Type4:
Demand:	On Hand:	Reserved:	
Backorder:	In QC: 500	Transit:	
Short:	Spoiled:	Rejected:	
Planned:	On Order:	On Hold:	
Destroyed:			
Material Warehouses			

+--- Materials -----+				
	Material:1	Type1:RAW	Type2:BEEF	Type3: Type4:
+--- Material Warehouses -----+				
	Id: 1	Name: Food Plant Warehouse		Safety: 0
	On Hand: 0	Reserved: 0		Backorder: 0
	In QC: 500	Transit: 0	Short: 0	Spoiled: 0
	Rejected: 0	Planned: 0		On Order: 0
	On Hold: 0			Destroyed: 0
+-----+				

55

User OPS\$USER

Lot Location Scan

Page 1 of 2

Date 08-AUG-94

```
+-- Materials -----+
|
| Material:1  Type1:RAW  Type2:BEEF  Type3:  Type4:  |
|
+-- Material Lots -----+
|
| Lot: 61      Demand:      In QC: 0      On Hand: 485 |
|
| Reserved:      On Hold:      Adjusted:      |
|
| Rejected:      Spoiled:      Destroyed:      |
|
| Transit:      Backordered:      Issued:      |
|
+-- Material Lot Locations -----+
+-----+
```

User OPS\$USER

Lot Location Scan

Page 2 of 2

Date 08-AUG-94

```
+--- Materials -----+
|
| Material:1  Type1:RAW  Type2:BEEF  Type3:  Type4:  |
|
+-- Material Lots -----+
|
|                               Lot: 61              |
|
+-- Material Lot Locations -----+
|
| Warehouse: 1      Status: RELEASED      Quantity: 485 |
|
| Reserved: 0      Area: LINE      Aisle: 1      Tier: 1      Bin: 1 |
|
+-----+
```

Figure 45: Materials | Inquiry | Lot Location Inquiry

Appendix I
Functional Hierarchy Diagram for Material Management Application

M

Materials
Management

... M1

Data take on for
materials
management

... M2

Request
inventory
replenishment

... M3

Receive, inspect
and store
shipment

... M5

Material
Movement

... M4

Material
Management
Maintenance

Inventory
reconciliation

M0

Data take on for materials management

M0.1

Warehouse data entry

M0.2

Warehouse area data entry

M0.3

Warehouse bin location data entry

M0.4

Area type data entry

M0.5

Area material restricted data entry

M0.6

Material Warehouse data entry

M0.7

Material data entry form.

M0.8

Material state data entry

M0.9

Material status data entry

M0.10

Material transaction type data entry

M0.11

Material lot data entry

M0.12

Material lot location data entry

Request inventory replenishment .

M1.1

Review current inventory levels at material warehouse level.

M1.3

Create a material requisition for material at low inventory

M1.2

Review inventory at the total material level.

M2

Receive, inspect and store shipment

M2.2

Receive materials

M2.2.1

Material physically moved off truck

M2.2.2

Create a new material lot with initial location at loading dock

M2.2.3

Mark pallets with status

M2.2.4

Determine location & move material from loading dock to inventory

M2.2.5

Place pallets in inventory at determined location and confirm

M2.1

Inspect Truck

M2.1.1

Verify PO and create delivery detail

M2.1.2

Check for foreign color, foreign odor and foreign material

M2.1.3

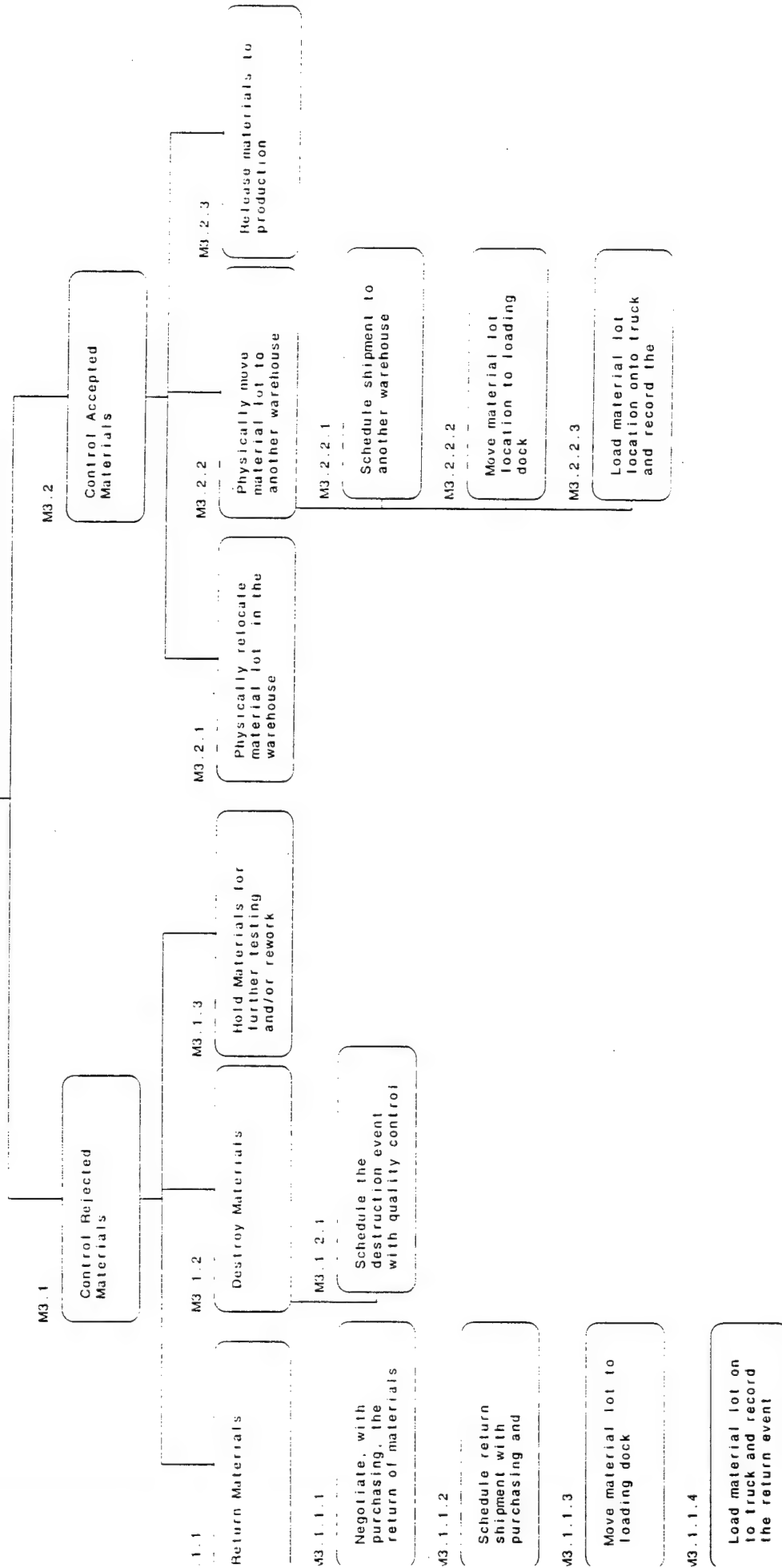
Check for certification

M2.1.4

Accept or Reject the truck contents or individual materials

M3

Material Movement



M4

Inventory
reconcilliation

M4.3

Material lot
adjustmtns

M4.3.1

Artificial status
change

M4.3.2

Lot run out

M4.2

Physical inventory

M4.2.X

Review and adjust
cycle times and
procedures with

M4.2.1

Review cycle time for
materials and
schedule physical

M4.2.2

Generate stock taking
report

M4.2.3

Perform physical
inventory

M4.2.4

Adjust inventory
records to match
physical inventory

M5

Material Management Maintenance

M5.1

Create, Update, or delete Warehouse data.

M5.2

Create, Update, or delete Warehouse area data.

M5.3

Create, Update or delete Warehouse Bin Location data.

M5.4

Create, update, or delete Area Type data.

M5.5

Create. Update or delete material state data.

M5.6

Create. Update or delete material status data.

M5.7

Create. Update or delete materials.

M5.8

Create, Update or delete area restrictions on materials.

Appendix II

Function to Entity Matrix Report

Oracle CASE*Dictionary
Function to Entity Matrix

- Function : M0.1

Definition: Warehouse data entry

Entity	Create	Retrieve	Update	Delete
WAREHOUSE	Y	Y	Y	Y

- Function : M0.10

Definition: Material Transaction Type data entry

Entity	Create	Retrieve	Update	Delete
MATERIAL TRANSACTION TYPE	Y	Y	Y	Y

- Function : M0.2

Definition: Warehouse Area data entry

Entity	Create	Retrieve	Update	Delete
WAREHOUSE AREA	Y	Y	Y	Y

- Function : M0.3

Definition: Warehouse Bin Location data entry

Entity	Create	Retrieve	Update	Delete
WAREHOUSE BIN LOCATION	Y	Y	Y	Y

- Function : M0.4

Definition: Area Type data entry

Entity	Create	Retrieve	Update	Delete
AREA TYPE	Y	Y	Y	Y

- Function : M0.5

Definition: Area Material Restricted data entry

Entity	Create	Retrieve	Update	Delete
AREA MATERIAL RESTRICTED	Y	Y	Y	Y

- Function : M0.6

Definition: Material Warehouse data entry

Entity	Create	Retrieve	Update	Delete
MATERIAL WAREHOUSE (DERIVED)	Y	Y	Y	Y

- Function : M0.7

Definition: Material data entry.

Entity	Create	Retrieve	Update	Delete
MATERIAL	Y	Y	Y	Y

- Function : M0.8

Definition: Material State data entry

Entity	Create	Retrieve	Update	Delete
MATERIAL STATE	Y	Y	Y	Y

- Function : M0.9

Definition: Material Status data entry

Entity	Create	Retrieve	Update	Delete
MATERIAL STATUS	Y	Y	Y	Y

- Function : M1.1

Definition: Review Current Inventory At Material Warehouse Level.

Entity	Create	Retrieve	Update	Delete
MATERIAL		Y		
MATERIAL CLASS		Y		
MATERIAL TYPE		Y		
MATERIAL WAREHOUSE (DERIVED)		Y		
WAREHOUSE		Y		

- Function : M1.2

Definition: Review Inventory At Total Material Level.

Entity	Create	Retrieve	Update	Delete
MATERIAL		Y		

- Function : M1.3

Definition: Create A Material Requisition For Material At Low Inventory

Entity	Create	Retrieve	Update	Delete
MATERIAL		Y		
MATERIALS MANAGER		Y		
REQUISITION	Y	Y	Y	
REQUISITION DETAIL	Y	Y	Y	

- Function : M2.1.1

Definition: Verify PO and Create Delivery Detail

Entity	Create	Retrieve	Update	Delete
DELIVERY	Y	Y	Y	
DELIVERY DETAIL	Y	Y	Y	
MATERIAL		Y		
MATERIAL LOT	Y	Y	Y	Y
MATERIAL LOT LOCATION	Y	Y	Y	Y
PURCHASE ORDER		Y		
PURCHASE ORDER ITEM		Y		
RECEIVING CLERK		Y		
WAREHOUSE		Y		
WAREHOUSE AREA		Y		
WAREHOUSE BIN LOCATION		Y		

• Function : M2.2.4

Definition: Determine Location and Move Material From Loading Dock to Inventory

Entity	Create	Retrieve	Update	Delete
AREA TYPE		Y		
DELIVERY		Y		
MATERIAL		Y		
MATERIAL AUDIT TRAIL	Y	Y	Y	Y
MATERIAL LOT		Y		
MATERIAL LOT LOCATION	Y	Y	Y	
MATERIAL TRANSACTION TYPE		Y		
PERSON		Y		
RECEIVING CLERK		Y		
WAREHOUSE AREA		Y		
WAREHOUSE BIN LOCATION		Y		

• Function : M2.2.5

Definition: Move Material Lot To Determined Location and Confirm

Entity	Create	Retrieve	Update	Delete
MATERIAL LOT		Y		

MATERIAL LOT LOCATION	Y	Y
ORGANIZATION LOCATION	Y	
WAREHOUSE BIN LOCATION	Y	

- Function : M3.1.1.2

Definition: Schedule Return Shipment With Purchasing and Quality Assurance

Entity	Create	Retrieve	Update	Delete
MATERIAL		Y		
MATERIAL LOT		Y		
RETURN	Y	Y		Y
RETURN DETAIL	Y	Y		Y

- Function : M3.1.1.3

Definition: Move Material Lot to Loading Dock

Entity	Create	Retrieve	Update	Delete
MATERIAL AUDIT TRAIL	Y	Y		Y
MATERIAL LOT		Y		
MATERIAL LOT LOCATION	Y	Y		Y
MATERIAL STATE		Y		
MATERIAL STATUS		Y		
MATERIAL TRANSACTION TYPE		Y		
PERSON		Y		

- Function : M3.1.1.4

Definition: Load Material Lot on to Truck and Record the Return Event

Entity	Create	Retrieve	Update	Delete
MATERIAL LOT		Y		Y
ORGANIZATION LOCATION		Y		
PERSON		Y		
RETURN		Y		Y
RETURN DETAIL		Y		
SHIPMENT	Y	Y		Y
SHIPMENT DETAIL	Y	Y		Y
SHIPMENT TYPE		Y		

- Function : M3.2.1

Definition: Physically Relocate Material Lot in the Warehouse

Entity	Create	Retrieve	Update	Delete
MATERIAL		Y		
MATERIAL AUDIT TRAIL	Y	Y	Y	
MATERIAL LOT		Y		
MATERIAL LOT LOCATION	Y	Y	Y	
MATERIAL TRANSACTION TYPE		Y		
PERSON		Y		
WAREHOUSE		Y		
WAREHOUSE AREA		Y		
WAREHOUSE BIN LOCATION		Y		

- Function : M3.2.2.1

Definition: Schedule Shipment to Another Warehouse

Entity	Create	Retrieve	Update	Delete
MATERIAL		Y		
MATERIAL LOT		Y		
MATERIAL LOT LOCATION		Y		
MATERIAL TRANSACTION TYPE		Y		

- Function : M3.2.2.2

Definition: Move Material Lot Location to Loading Dock

Entity	Create	Retrieve	Update	Delete
MATERIAL		Y		
MATERIAL AUDIT TRAIL	Y	Y	Y	Y
MATERIAL LOT		Y		
MATERIAL LOT LOCATION		Y	Y	
MATERIAL TRANSACTION TYPE		Y		

- Function : M3.2.2.3

Definition: Load Material Lot Location Onto Truck and Record the Shipment

Entity	Create	Retrieve	Update	Delete
MATERIAL		Y		
MATERIAL LOT		Y		
MATERIAL LOT LOCATION		Y		
SHIPMENT	Y	Y	Y	
SHIPMENT DETAIL	Y	Y	Y	
SHIPMENT TYPE		Y		
SHIPPING CLERK		Y		

- Function : M3.2.3

Definition: Release Materials To Production

Entity	Create	Retrieve	Update	Delete
MATERIAL		Y		
MATERIAL LOT		Y	Y	
MATERIAL LOT LOCATION		Y	Y	
MATERIAL WAREHOUSE (DERIVED)		Y	Y	
WAREHOUSE		Y		

- Function : M4.2.1

Definition: Review Cycle Time for Materials and Schedule Physical Inventory.

Entity	Create	Retrieve	Update	Delete
MATERIAL		Y		
MATERIAL CLASS		Y		
MATERIAL WAREHOUSE (DERIVED)		Y		
MATERIALS MANAGER		Y		

- Function : M4.2.2

Definition: Generate Stock Taking Report

Entity	Create	Retrieve	Update	Delete
--------	--------	----------	--------	--------

MATERIAL	Y
MATERIAL LOT	Y
MATERIAL LOT LOCATION	Y
MATERIAL WAREHOUSE (DERIVED)	Y
WAREHOUSE BIN LOCATION	Y

- Function : M4.2.4

Definition: Adjust Inventory Records To Match Physical Inventory

Entity	Create	Retrieve	Update	Delete
MATERIAL	Y		Y	
MATERIAL LOT	Y		Y	
MATERIAL LOT LOCATION	Y		Y	
MATERIAL WAREHOUSE (DERIVED)	Y		Y	
MATERIALS MANAGER	Y			

- Function : M4.2.5

Definition: Review and Adjust Cycle Times and Procedures with Accounting

Entity	Create	Retrieve	Update	Delete
MATERIAL	Y			
MATERIAL CLASS	Y			
MATERIAL WAREHOUSE (DERIVED)	Y		Y	
WAREHOUSE	Y			

- Function : M4.3

Definition: Material Lot Adjustments

Entity	Create	Retrieve	Update	Delete
MATERIAL	Y		Y	
MATERIAL LOT	Y		Y	
MATERIAL LOT LOCATION	Y		Y	
MATERIAL WAREHOUSE (DERIVED)	Y		Y	

- Function : M4.3.1

Definition: Artificial Status Change

Entity	Create	Retrieve	Update	Delete
MATERIAL AUDIT TRAIL	Y	Y	Y	
MATERIAL LOT		Y	Y	
MATERIAL LOT LOCATION		Y	Y	
MATERIAL STATE		Y		
MATERIAL STATUS		Y		
MATERIAL TRANSACTION TYPE		Y		

- Function : M4.3.2

Definition: Lot Run Out

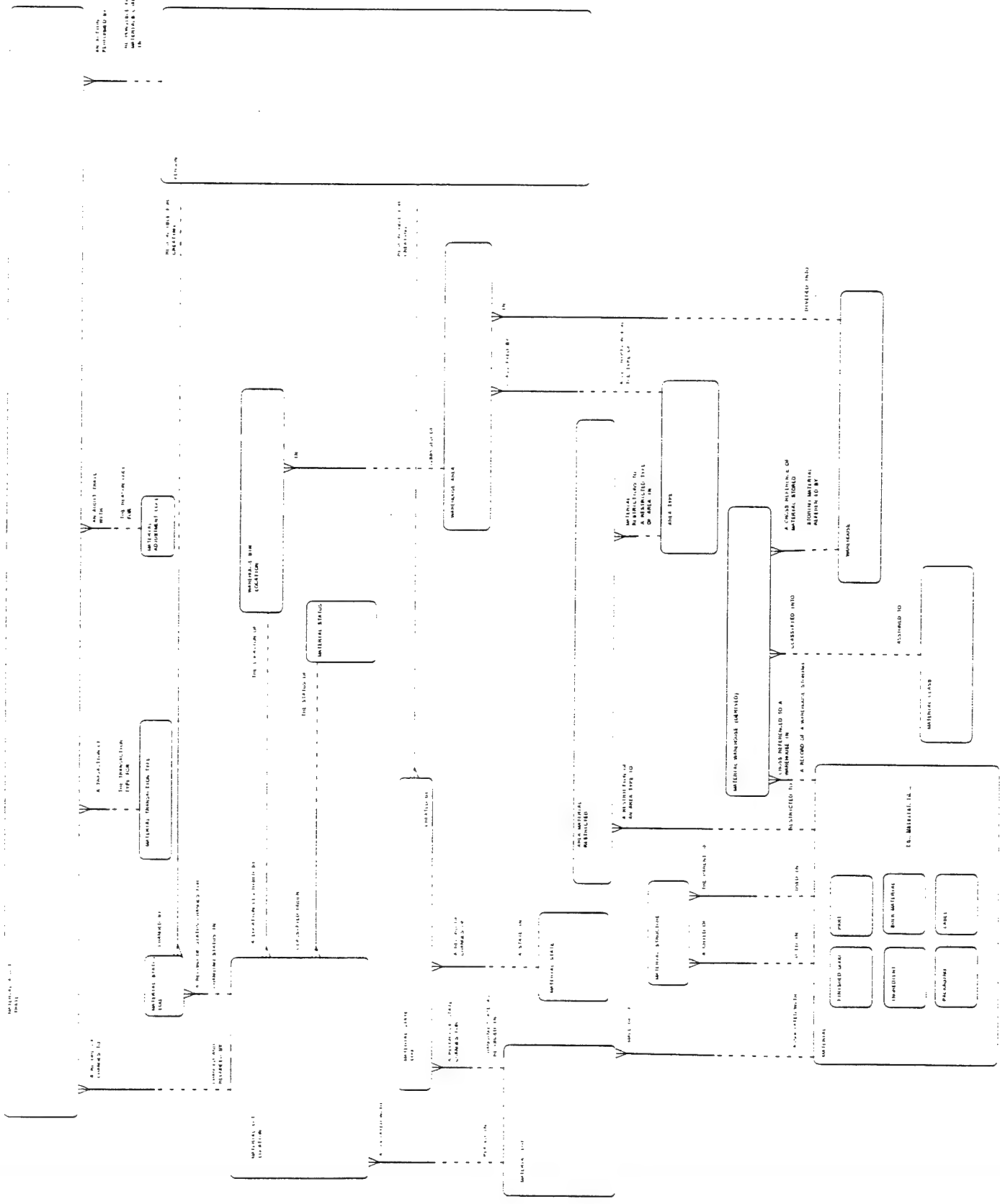
Entity	Create	Retrieve	Update	Delete
MATERIAL		Y		
MATERIAL LOT		Y		
MATERIAL LOT LOCATION		Y	Y	
MATERIAL STATE		Y		
MATERIAL STATUS		Y		

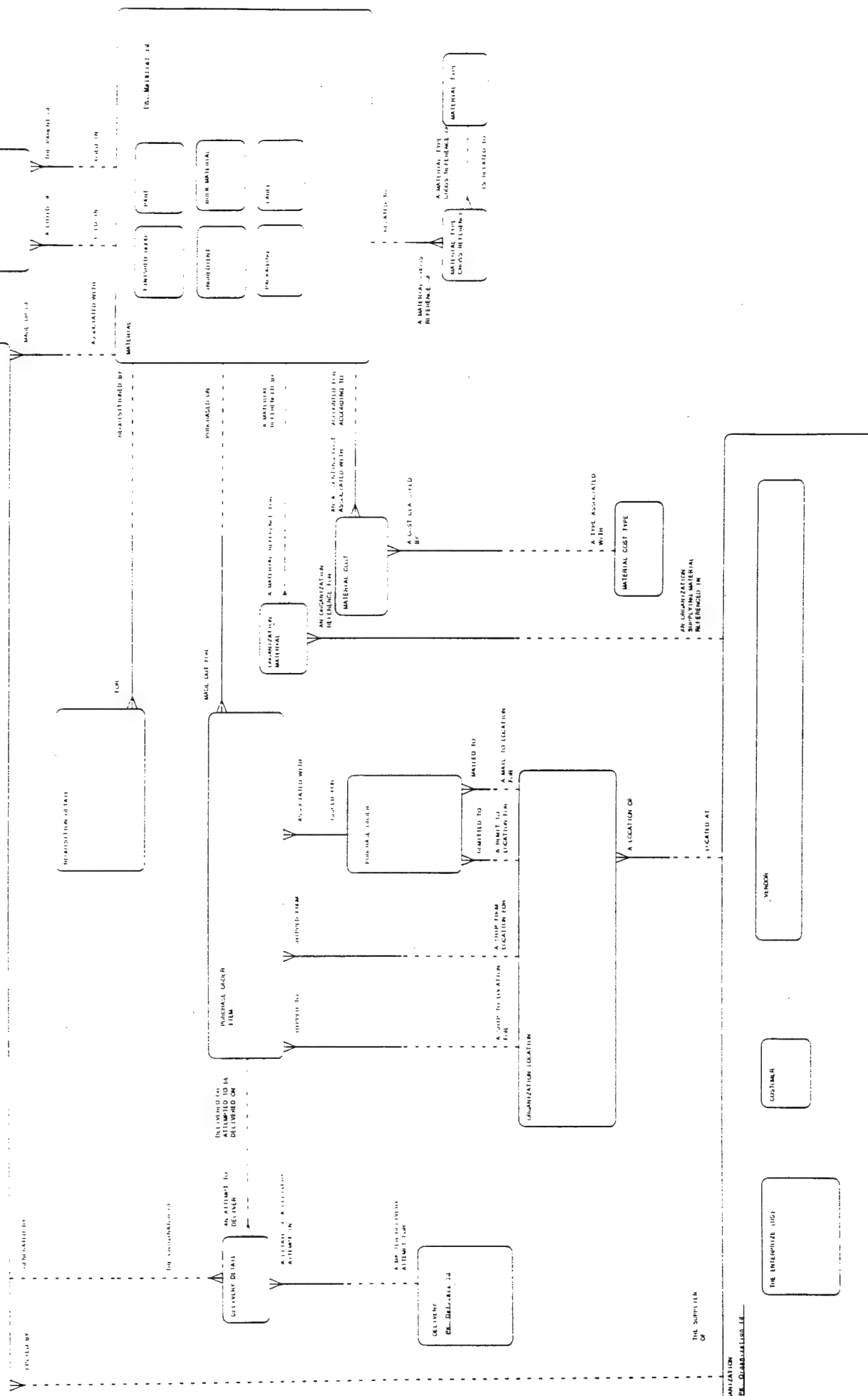
Appendix III
E-R Diagram for the Material Management Application

FIG. 1. PLAN
PREFORMED BY
THE CONTRACTOR
AND THE
OWNER'S
REPRESENTATIVE

FIG. 2. SECTION
PREFORMED BY
THE CONTRACTOR
AND THE
OWNER'S
REPRESENTATIVE

FIG. 3. SECTION
PREFORMED BY
THE CONTRACTOR
AND THE
OWNER'S
REPRESENTATIVE





Appendix IV

Entity Definition Report

Oracle CASE*Dictionary
Entity Definitions

- **AREA MATERIAL RESTRICTED**

Certain materials may be restricted from certain areas. Only restricted material can be stored in a restricted area. ex. beef must be stored in the restricted area freezer.

- **AREA TYPE**

Each area may be classified as being of a certain type. ex. an area may be restricted to frozen material.

- **BULK MATERIAL**

Material made up in batches and stored or used as a bulk material in recipes.

- **CUSTOMER**

The entities to which the enterprise sells its products.

- **DELIVERY**

A record of every attempted delivery event. Each time a truck pulls up to the enterprise's warehouse, a delivery log must be filled out. This log contains several delivery details which indicate the conditions of the truck and each of its contents.

- **DELIVERY DETAIL**

Delivery details for each PO line item.

- **DESTRUCTION DETAIL**

A list of material lots destroyed during one destruction event.

- **DESTRUCTION LOG**

A log of material which were destroyed.

- **FINISHED GOOD**

Materials in a saleable form.

- **FORKLIFT OPERATOR**

An employee who operates the forklift machine. This machine is used to move raw materials to production. to move finished goods into the warehouse and to move any large items.

- **INGREDIENT**

Materials used to make a product. Includes all food items such as beef, vegetables, water, flour, etc.

- **LABEL**

Material placed on the container as per the customer's order.

- **LOCATION RELATIONSHIP**

The relationships between various organization locations.

- **LOCATION RELATIONSHIP TYPE**

The type of the location relationship.

- **MATERIAL**

The ingredients, packaging, parts, and supplies ordered by the enterprise from vendors. These are used to produce products, repair and maintain machines and.

- **MATERIAL ADJUSTMENT CODE**

Codes which indicate the reason for an adjustment to a material.

- **MATERIAL AUDIT TRAIL**

An audit trail for all transactions involving any materials. This includes any material moves, receipts, issues, shipments, adjustments, in transit, etc.

- **MATERIAL CLASS**

The APICS (American Production and Inventory Control Society) classification for the material. This is used in cycle counting and material control.

- **MATERIAL COST**

The cost structure for a material. Includes the type and a cost.

- **MATERIAL COST TYPE**

The types of accounting costs associated with different materials.

- **MATERIAL LOT**

Lots of Raw materials sent from vendors and received, stored and used in production by the enterprise.

- **MATERIAL LOT LOCATION**

An entity that keeps track of the amount of the material lot stored in raw material inventory by location.

- **MATERIAL STATE**

A group of material states. (Ex. In QC, Accepted, Rejected, and Runout)

- **MATERIAL STATE LOG**

A record of all states changes for a material lot.

- **MATERIAL STATUS**

The STATUS is an entity to identify the location status in which materials remain. Statuses will vary with states. Statuses include accepted, in-transit, spoiled, return, destroyed, etc.

- **MATERIAL STATUS COMBINATION**

The set of valid combinations of statuses that can be used when changing from one status to another.

- **MATERIAL STATUS LOG**

A record of all status changes on a given location.

- **MATERIAL STRUCTURE**

The structure reference for materials, sub-assemblies, bulk materials and finished products.

- **MATERIAL TRANSACTION TYPE**

A list of transactions that can be performed on materials.

- **MATERIAL TYPE**

The different types of materials. i.e. finished goods, raw materials.

- **MATERIAL TYPE CROSS REFERENCE**

A given material type is related to multiple materials. Between material type and material, there are many-to-many relationship. The entity is the cross reference between material and material type. This will help us identify the relationship between material and material type.

- **MATERIAL WAREHOUSE (DERIVED)**

Material Warehouse is a cross reference between material and warehouse It will allow the user to easily determine the amount of a material in a warehouse at present. This is a derived entity.

- **MATERIALS MANAGER**

The manager of materials inventory.

- **ORGANIZATION**

A supertype entity for any organization. Sub-types include vendor, customer and the enterprise.

- **ORGANIZATION LOCATION**

The location of an organization.

- **ORGANIZATION MATERIAL**

A Cross reference between the org. and the material entities that enforces a one to one correspondence.

- **PACKAGING**

Material used to package the product. Includes cans, tray packs, pouch material, paper, cardboard, wax paper, etc.

- **PART**

Materials used to repair or maintain machines and equipment.

- **PERSON**

People who do work for the enterprise. This is a supertype for Purchasing agent, supervisor and others.

- **PURCHASE ORDER**

A request by the enterprise to buy materials or supplies from a vendor. A purchasing agent can create a purchase order. Purchase orders must be approved by the purchasing manager.

- **PURCHASE ORDER ITEM**

A Detail of the Purchase order by line item. Includes the specific material, quantity, price per unit and delivery date.

- **RECEIVING CLERK**

An employee responsible for receiving materials and supplies.

- **REQUISITION**

A request to purchasing to order some material.

- **REQUISITION DETAIL**

A detail request item for a material requisition.

- **RETURN**

A return event sends material lots back to the vendor. Each Return is a grouping of several lots which were returned at one time.

- **RETURN DETAIL**

Detailed list of the lots returned to a vendor.

- **SHIPMENT**

An entity that records outbound shipments.

- **SHIPMENT DETAIL**

Details about each shipment.

- **SHIPMENT TYPE**

The type of shipment being made. i.e. Return, finished goods, to destruction, etc.

- **SHIPPING CLERK**

An employee responsible for shipping products or returning defective materials.

- **SUPERVISOR**

An employee who supervises some aspect of operations.

- **VENDOR**

Companies that sell Materials and supplies to the enterprise. Also may provide services such as maintenance, repair, shipping, etc.

- **WAREHOUSE**

A warehouse is a place where materials can be stored.

- **WAREHOUSE AREA**

A warehouse is divided into many areas. This is a record of every area in every warehouse.

- **WAREHOUSE BIN LOCATION**

The locations of bins in a warehouse that may be used for storage.

Appendix V

Entity Relationship Report

- Each area material restricted must be a restriction of an area type to one and only one material
- Each area type may be a description for the type of one or more warehouse areas
- Each area type may be a restricted type of area in one or more area materials restricted
- Each area material restricted must be material restrictions to one and only one area type
- Each delivery detail may be the originator of one and only one material lot
- Each delivery detail must be a detail of a delivery attempt in one and only one delivery
- Each delivery detail must be an attempt to deliver one and only one purchase order item
- Each delivery may be a master delivery attempt for one or more delivery details
- Each destruction detail must be a cross reference for one and only one destruction log
- Each destruction detail must be a cross reference of destruction for one and only one material lot
- Each destruction log may be the master log of one or more destruction details
- Each destruction log must be supervised by one and only one supervisor
- Each delivery must be filled out by one and only one receiving clerk
- Each location relationship may be ranked by preference for one and only one material
- Each location relationship must be a relationship from one location for one and only one organization location
- Each location relationship must be a relationship to a location for one and only one organization location
- Each location relationship must be relate to locations by a type defined one and only one location relationship type

- Each location relationship type may be a relationship between locations for one or more location relationships
- Each material adjustment code may be the reason code for one or more material audit trails
- Each material audit trail must be a record of changes to one and only one material lot location
- Each material audit trail must be a transaction of one and only one material transaction type
- Each material audit trail must be an action performed by one and only one person
- Each material audit trail must be an audit trail with one and only one material adjustment code
- Each material class may be assigned to one or more material warehouses
- Each material cost must be a cost classified by one and only one material cost type
- Each material cost must be an accounting cost associated with one and only one material
- Each material cost type may be a type associated with one or more material costs
- Each material lot location may be changed and recorded by one or more material audit trails
- Each material lot location may be changing status in one or more material status logs
- Each material lot location may be shipped on one or more shipment details
- Each material lot location must be a location described by one and only one warehouse bin location
- Each material lot location must be associated with one and only one material lot
- Each material lot location must be classified under one and only one material status
- Each material lot may be changing state as recorded in one or more material

- Each material lot may be destroyed and recorded by one or more destruction details
- Each material lot may be generated by one or more delivery details
- Each material lot may be placed in one or more material lot locations
- Each material lot may be returned on one or more return details
- Each material lot may be supplied by one and only one organization
- Each material lot must be made up of one and only one material
- Each material may be a material referenced by one or more organization materials
- Each material may be accounted for according to one or more material costs
- Each material may be associated with one or more material lots
- Each material may be cross referenced to a warehouse in one or more material warehouses state logs
- Each material may be purchased on one or more purchase order items
- Each material may be related to one or more material type cross references
- Each material may be requisitioned by one or more requisition details
- Each material may be restricted to one or more area materials restricted
- Each material may be supplied by locations based on priority assigned in one or more location relationships
- Each material may be used in one or more material structures
- Each material may be used in one or more material structures
- Each material state log must be a record of changes of one and only one material state
- Each material state log must be a record of state changes for one and only one material lot
- Each material state log must be created by one and only one person
- Each material state may be a state in one or more material state logs
- Each material status log must be a record of status changes for one and only one material lot location

- Each material status log must be changed by one and only one person
- Each material status may be the status of one or more material lot locations
- Each material structure must be a child of one and only one material
- Each material structure must be the parent of one and only one material
- Each material transaction type may be the transaction type for one or more material audit trails
- Each material type cross reference must be a material cross reference of one and only one material
- Each material type cross reference must be a material type cross reference of one and only one material type
- Each material type may be related to one or more material type cross references
- Each material warehouse (derived) may be classified into one and only one material class
- Each material warehouse (derived) must be a cross reference of material stored one and only one warehouse
- Each material warehouse (derived) must be a record of a warehouse storing one and only one material
- Each organization location may be a remit to location for one or more purchase orders
- Each organization location may be the originating location of one or more shipments
- Each organization location may be a from participant in one or more location relationships
- Each organization location may be a mail to location for one or more purchase orders
- Each organization location may be a ship from location for one or more purchase order items
- Each organization location may be a ship to location for one or more purchase order items
- Each organization location may be a to participant in one or more location relationships

- Each organization location may be the destination of one or more shipments
- Each organization location may be the location of one or more warehouses
- Each organization location may be the supplier of one or more requisitions
- Each organization location must be a location of one and only one organization
- Each organization material must be a material reference for one and only one material
- Each organization material must be an organization reference for one and only one organization
- Each organization may be an organization supplying material referenced in one or more organization materials
- Each organization may be located at one or more organization locations
- Each organization may be the supplier of one or more material lots
- Each person may be responsible for creating one or more material state logs
- Each person may be responsible for creating one or more material status logs
- Each person may be responsible for materials changes in one or more material audit trails
- Each person may be the requestor of one or more requisitions
- Each purchase order item may be delivered or attempted to be delivered on one or more delivery details
- Each purchase order item must be associated with one and only one purchase order
- Each purchase order item must be made out for one and only one material
- Each purchase order item must be shipped from one and only one organization location
- Each purchase order item must be shipped to one and only one organization location
- Each purchase order must be issued for one or more purchase order items
- Each purchase order must be mailed to one and only one organization location
- Each purchase order must be remitted to one and only one organization location

- Each receiving clerk may be responsible for filling out one or more deliveries
- Each requisition detail must be a detail requisition item of one and only one requisition
- Each requisition detail must be for one and only one material
- Each requisition must be a master requisition with one or more requisition details
- Each requisition must be a requisition created by one and only one person
- Each requisition must be requested from one and only one organization location
- Each return detail may be a return shipped on one or more shipment details
- Each return detail must be a detail of one lot returned by one and only one return
- Each return detail must be a return of one and only one material lot
- Each return may be a collection of lots in one or more return details
- Each shipment detail may be a shipment of one and only one material lot location
- Each shipment detail may be the shipment item for one and only one return detail
- Each shipment detail must be a detail of items on one and only one shipment
- Each shipment may be a shipment with one or more shipment details
- Each shipment must be of one and only one shipment type
- Each shipment must be shipped by one and only one vendor
- Each shipment must be shipping from one and only one organization location
- Each shipment must be shipping to one and only one organization location
- Each shipment type may be the type of one or more shipments
- Each supervisor may be responsible for supervising one or more destruction logs
- Each vendor may be the trucking company used to ship one or more shipments
- Each warehouse area may be composed of one or more warehouse bin locations
- Each warehouse area must be classified by one and only one area type

- Each warehouse area must be in one and only one warehouse
- Each warehouse bin location may be the location of one or more material lot locations
- Each warehouse bin location must be in one and only one warehouse area
- Each warehouse may be divided into one or more warehouse areas
- Each warehouse may be storing material referenced by one or more material warehouses
- Each warehouse must be located at one and only one organization location

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**COMBAT RATION
ADVANCED MANUFACTURING
TECHNOLOGY DEMONSTRATION
(CRAMTD)**

**Data Acquisition and Monitoring of the
Tray Pack Line**

Technical Working Paper (TWP) 103

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Department of Industrial Engineering**

June 1995

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1. Introduction

This document is an update to the previous technical working paper, TWP #88, "Level 2 Automation of Tray Pack Line" concerning task item 3.5.2 of STP #16. That task item requires the implementation of an automation strategy at level 2 for the Tray Pack Line. The architecture of the plan is to acquire data from the production line using the Allen Bradley Series 5 Programmable Logic Controller (PLC) and then send it to shop floor PC. Some retrieved data will be manipulated in the PC through some applications. Finally, processed data will be uploaded to a central database for record keeping.

In the previous report, PLC implementation of the plan has been discussed in detail. The scope of this report will be the automatic data acquisition from PLC to the shop floor PC and the connection to central data base. FIX DMACS, an industrial automation software, is used to achieve this end. In the following sections implementation of FIX DMACS will be presented in detail. First, a brief description of FIX DMACS features is given in section 2.

2. A Brief Overview of FIX DMACS:

FIX DMACS is a PC based SCADA (Supervisory Control and Data Acquisition) software used to collect the necessary data from the shop floor. FIX stands for **Fully Integrated Control System** and DMACS stands for the **Distributed Manufacturing Automation and Control Software**. It uses a graphical interface to acquire, present and manage the data. After retrieving the data, FIX DMACS can also manipulate and process the raw data according to the user's needs. The processing of the data can be time-based or exception based. If time-based processing is chosen, data is processed after every time period specified by the user. If exception-based processing is chosen, data is processed when an event occurs. The event can be: data changes, unsolicited messages from the process hardware, operator actions, or software applications. Examples of exception-based and time-based processing for the Tray Pack Line will be given in section 4.

In addition to manipulating and displaying the real-time shop floor data, FIX DMACS provides three other SCADA functions: supervisory control, alarming and control. Through *supervisory control*, FIX DMACS allows the operator to change set points and other key points from the computer. *Alarming* is the ability to recognize exceptional events and immediately report those

events. Finally through *control* features, it is possible to control the process by automatically applying algorithms that adjust process values to maintain certain parameters within their set limits.

FIX DMACS is flexible enough to operate in distributed processing environment as well as a centralized processing environment. It can be used for applications requiring only one node or several nodes processing over a network. In this project, the set up will consist of a view node operating in the shop floor and a SCADA node operating in a control room. More view nodes can be added to this setup to be used in different units of the plant, like quality control lab.

The basic architecture of FIX DMACS, shown in figure 2.1, consists of the following:

- I/O driver
- Driver Image Table (DIT)
- Scan, Alarm, and Control (SAC) program
- Database
- Internal database access software
- Software applications

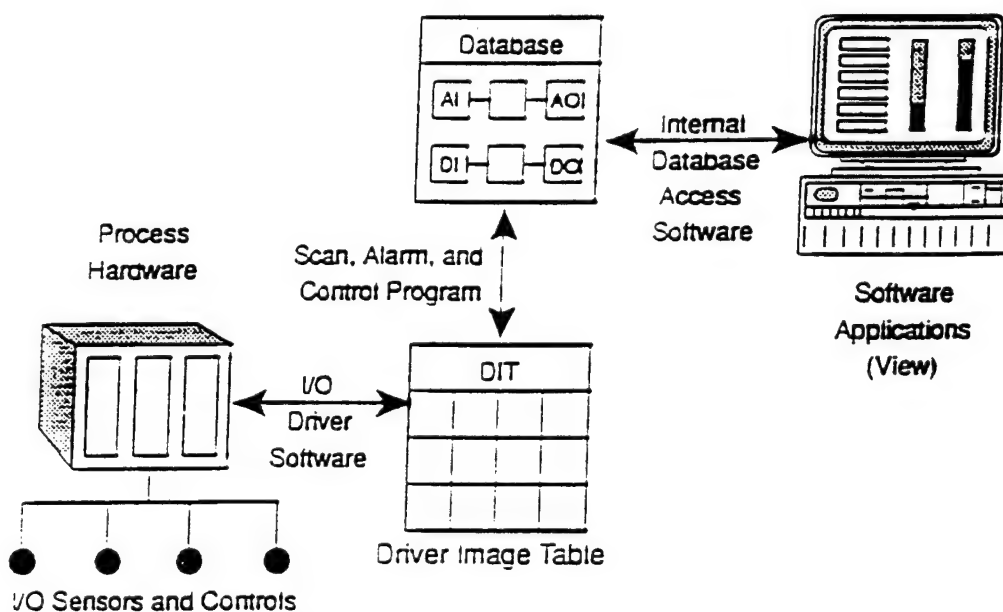


Figure 2.1: Basic architecture of FIX DMACS

I/O driver is the software interface to the PLC that reads or writes data from/to the registers. The user specifies the necessary registers using the *I/O driver configuration task*. The *Driver Image Table* is like a spread sheet which holds the data from the specified register of the PLC. Each cell in the DIT is called a poll record. Detailed information will be given in the next section about *I/O driver* and poll record configurations.

The *Scan, Alarm, and Control program* is the link between DIT and the database. SAC transfers data from the DIT to the database or writes data to the DIT from the database, transforms data into necessary format for the database, generates alarm messages if the data is outside the alarm limits, identifies any exceptions and executes the control logic of the process database. More details on alarming will be presented in section 6.

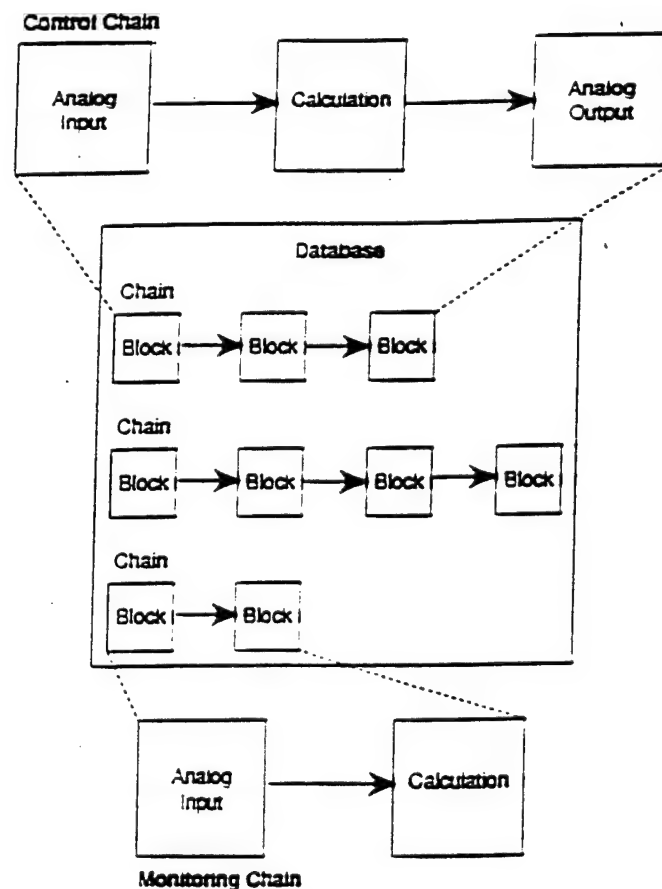


Figure 2.2: Database Blocks and Chain Structure

The process *Database* manipulates and processes raw data from the PLC according to the user's needs. The Database Builder program is used to create the database, which is made up of blocks and chains. A block performs a specific task using a coded set of process control instructions. A chain contains more than one block linked together to form a control loop. If, for example, you want to add two data points which you retrieve from PLC and write it back to PLC, the chain will consist of two Analog Input blocks connected to a Calculation block, which is connected to an Analog Output block. There are many different types of blocks, allowing one to manipulate the data chain in almost any conceivable way. Different block types and how they are used in the Tray Pack line implementation will be given in section 4. For the time being figure 2.2 shows a prototype chain structure of the process database.

The *Internal database access software* transfers the processed data from database to the necessary software applications. The two graphic *software applications* are Draw and View. The designer uses Draw to create the displays and operator interfaces. View shows the changes in display in real time as the process data changes. Hence the operator can monitor the production line from the display shown in View. Operator screens designed for Tray Pack Line will be described in section 5.

Under the architecture of FIX DMACS, a typical data flow cycle in Tray Pack Line will be as follows: There are fiber optic sensors on the Tray Pack line which monitors certain characteristics of the tray (e.g. check if a tray is mounded or not) or the process (e.g. check if the discharge conveyor is full or not). These are the I/O sensors for Tray Pack line. Let's concentrate on one of these sensors, say, the one which checks discharge conveyor. Once the discharge conveyor is full, the sensor sends a signal to PLC 5/12. The signal is captured in a register in PLC 5/12 which in turn is transferred to DIT through the I/O driver. Then SAC program grabs the data from DIT, transforms it into the necessary format and sends it to a digital input (DI) block in the database. In the database DI might be in a chain with a digital alarm (DA) block. Since the status of discharge conveyor is changed from empty to full (i.e. the value of the data changed from 0 to 1, or vice versa), the operator should be warned of the situation. Internal database access software sends this data to the operator screen in View program. Depending on the screen design a visual signal (like a blinking light, or a message line) will appear on the screen. In the meantime, SAC also alarms the

operator of the new status through messages or horns. This concludes the flow of data in a data acquisition cycle. Since FIX DMACS is capable of supervisory control of the line as well, by clicking on a push button on the screen the operator may execute a program to control a process while he/she clears the existing problem about the discharge conveyor. In this case, upon execution of the program, related data and set points travel through the same path in reverse direction and data is written back to PLC. For the time being, only the data acquisition cycle of FIX DMACS is implemented on the Tray Pack line and existing software development does not include supervisory control yet.

3. System Configuration

In order to perform automated tasks in a production line, the first thing needed is to retrieve raw data from the process. Therefore, before starting to set up the database for the tray pack line, I/O driver and poll records have to be configured. Three I/O drivers are configured for the application; ABK, SIM and DDE.

ABK I/O driver is a tool for accessing data from hardware registers and for specifying communication parameters. Here we use Allen-Bradley Data Highway Plus via KT card (Rev. 4.27 bL) to provide the connection between the PLC and the PC. FIX DMACS provides a *Channel Definition Screen* where KT card is configured. This screen can be accessed by first double clicking on System Configuration icon and then the ABK icon. The *Memory Address* for KT card is set to be **CC00**, *PC Station Number* is set to **41**.

The second step is to describe the hardware devices that we will be accessing, through the AB Data Highway Plus. For Tray Pack line the hardware option is PLC5/12 and the *Primary Station Address* is set to **20**. This information can be accessed at a *Device Description Screen* (from channel description screen) by pressing F5.

Once FIX DMACS is provided with this information, the I/O driver can build and maintain the DIT. If DIT is viewed as a collection of mailboxes, then each poll record can be viewed as an individual mailbox. To create a poll record, we need to specify a starting address and the length. The starting address tells the I/O driver where the range of data in the PLC begins and the length specifies how many data points to fetch. See figure 3.1 below for a generic illustration. The designer should

note that the poll record definition format is different for different hardware options. Refer to the *I/O Driver Manual* to check for poll record formats of different hardware options.

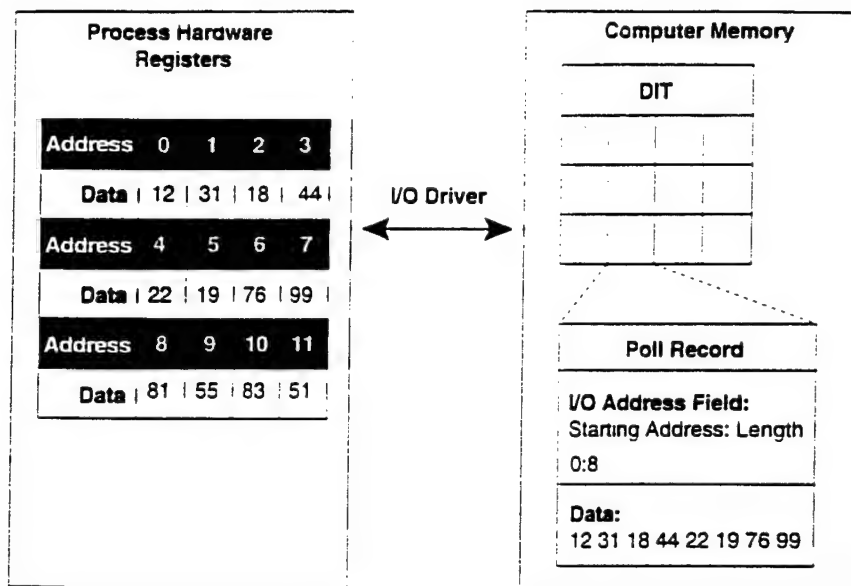


Figure 3.1: A Poll Record Example

In configuration of the poll records for the Tray Pack line, we are mainly interested in 4 types of data; external inputs, internal inputs, counters and timers. External inputs are the inputs related to the sensors and push buttons in the line. Internal inputs are the bits set in PLC through the execution of the ladder logic. These two types of data are used to check the state of the system such as, normal running conditions, fault and alarm conditions and system ready conditions. Counter and timer addresses are also configured as poll records for the Tray Pack line. The counters of PLC 5/12 give information about the production volume and quality by keeping track of the number of filled, mounded, underweight, total rejected and total seamed trays. Finally timers are monitored to get information about the production efficiency, by keeping track of the downtime and production times. Table 3.1 summarizes the poll record configuration of the tray pack line. For detailed information on the specific addresses of these 4 data types and their functions refer to TWP #88.

Once I/O driver and poll records are configured, we can retrieve data from the process hardware and store in DIT which is a sort of buffer between the process and the database. In the next

section we will describe how to relate each poll record with a block in database. Before then, we would like to give a brief description on the other two drivers.

Type of Data	Data type: Starting address:Length
External Inputs	I:3:2
	I:11:1
Internal Inputs	B3:0:3
	B3:5:1
	B3:13:1
Counters	C5:1:6
Timers	T4:8:1
	T4:52:1

Table 3.1: Summary of Poll Records for Tray Pack Line

SIM (Simulation Driver) is an internal driver provided by the FIX DMACS. One may simulate an operation through Simulation Driver by ramping up or down the values of some registers reserved by FIX DMACS. Demo Mode of FIX DMACS can be given as an example which uses this SIM driver. The software may run for two hours in Demo Mode without requiring the activation key and all the sample operations are governed by SIM during these two hours course of action. In the Tray Pack implementation we used SIM mainly for applications when manual entries are made from the screen or setting up flags for display development so that certain dynamic behavior of some objects may be controlled.

FIX DMACS also supports Dynamic Data Exchange through DDE driver. Through this driver, it is possible to transfer data to or from other software applications that have a DDE interface. For Tray Pack line, we attempt to use DDE to integrate a stand alone quality control application, PMCOMM, with the operator screens designed. This application can be described as follows: At

certain time intervals during the production, operator or quality control personnel takes samples from the line and weighs them on a scale. The scale is connected to a PC. PMCOMM automatically reads the value from the scale and performs some statistical analysis on the data. This way, any human error that might be caused by a manual entry of the sample weights are eliminated. The drawback is that the data cannot be sent directly to the plant database by PMCOMM. FIX DMACS and PMCOMM are linked by DDE driver to avoid their inherent drawbacks. Once PMCOMM grabs a data from the scale, FIX DMACS reads that related register or address through DDE and some push buttons on the operator screen and data is then processed in FIX DMACS and sent to plant database, thus eliminating any human error.

For more details on system configuration refer to *I/O Driver Manual* and *System Setup Manual*.

4. The Database

A brief introduction on the structure of FIX DMACS database was given in section 2. As mentioned earlier, the database consists of blocks. When building the database each block is assigned a name. This is called the *tag name* of the block. Through poll records we retrieve a bunch of data points all together. In application, however, we need to identify and utilize each individual data point (i.e. a bit or a register in PLC). Hence, *tag names* are designer defined names given to each data point in the FIX DMACS database. Whenever a particular piece of information is needed in a FIX DMACS application, it will be called by its tag name (rather than its address in the PLC).

Since database is responsible for data processing as well as data acquisition of different types of data, there are separate types of blocks. In the Tray Pack line database we have not utilized all the different kind of blocks. Table 4.1 shows the block types and the related abbreviations used in this document.

Block Type	Abbreviation
Analog Input Block	AI
Analog Output Block	AO
Boolean Block	BL
Calculation Block	CA
Digital Alarm Block	DA
Digital Input Block	DI
Digital Output Block	DO
Statistical Data Block	SD
SQL Data Block	SQD
SQL Trigger Block	SQT
Program Block	PG
Timer Block	TM
Totalizer Block	TT
Text Block	TX

Table 4.1: List of Blocks used in Tray Pack Line database design

In this section a detailed description of the database that is built for Tray Pack Line will be presented. Figures 4.2 through 4.18 illustrates the blocks in Tray Pack Line database and the flow of data between them. Figure 4.1 is the legend for the following 18 figures.

Not all the blocks in the database are in a chain with others. The following list of blocks is not in a chain with any other block, yet it is used in the design of operator interfaces to signal fault conditions of the Tray Pack Line. Note that all these blocks are digital inputs and outputs, that is, they are either external or internal inputs acquired from PLC or SIM driver.

Tag Name	Type	Description
AUTO_MAN	DI	SS-2 Automatic/Manual Mode
CARR_FLT	DI	Carrier Fault
CK_WEIGHT	DI	Zero Speed in Check weigher
CNT_COMP	DI	Count complete
CON_SEL_SW	DI	Individual Auto/Man Conveyor Selector Switch
FILL_CONV	DI	Overload in Filler Conveyor (OL-4)
LID_CONV	DI	Overload in Lid Conveyor (OL-3)
LID_POS	DI	Lid Position
MAIN_DRIVE	DI	Overload in Main Drive (OL-1)
NO_CV_BD	DI	No cover/ No body
NO_VAC	DI	No vacuum
OL_CK_WHT	DI	Overload in Check weigher (OL-7)
OL_PHASE	DI	Overload in phasing conveyor (OL-5)
OL_REJ_DVR	DI	Overload in Reject diverter (OL-8)
OL_REJ_LN	DI	Overload in Reject Lane (OL-9)
OL_SPACE	DI	Overload in Spacing conveyor (OL-6)
OVER_TORQ	DI	Overtorque
PHA_CONV	DI	Zero Speed in Phasing conveyor
POWERON	DI	Control power on
REJ_DIVERT	DI	Zero speed in reject diverter
REJ_LANE	DI	Zero speed in reject lane
RUN_CNT_SW	DI	Run/Count SS-1
SPA_CONV	DI	Zero speed in spacing conveyor
SYS_START	DI	System Start Push Button (PB-5)
SYS_STOP	DI	System Stop Push Button (PB-6)

VAC_PUMP	DI	Overload in vacuum pump (OL-2)
WHEEL_I_O	DI	Wheel in/out
FLAG	DO	Trigger for “Saving...” Message in View
M_DUMMY1	DO	Dummy Blck used in Material Tracking Screen
M_DUMMY2	DO	Dummy Blck used in Material Tracking Screen
M_DUMMY3	DO	Dummy Blck used in Material Tracking Screen
M_DUMMY4	DO	Dummy Blck used in Material Tracking Screen
M_DUMMY5	DO	Dummy Blck used in Material Tracking Screen

Table 4.2: Digital Inputs and Outputs that are not in a chain with other blocks in the database

In the Tray Pack Line implementation we have mainly focused on 5 types of activities;

- Reading the data from PLC or Operator Interface.
- Manipulating the data
- Using the data in supervision of the process.
- Receiving input from plant database
- Writing back to plant database

We can look into some of the chains illustrated in figures 4.2 through 4.18 in detail to understand how the above goals are achieved. Figure 4.2 illustrates some basic chains, where data is read from PLC by an AI block. The CA block then converts the raw data into the desired format. A more complex chain is shown in figure 4.3 and discussed below. Refer to the appendix for the figures 4.3 through 4.18.

One of the major information we collect from the Tray Pack Line is the weight of the trays. To collect this data we need to read the register, I:011, in PLC 5/12. This register contains a BCD (Binary Coded Decimal) data which is passed from the Check weigher as each tray is weighed. The BCD data is composed of 4 sets of numbers each with 4 bits with a total of 16 bits (Refer to TWP #88 for more detail on BCD data). Therefore, when we set up an AI block to read the register, we get a value, where the number 0 in decimal is represented by 32768 (i.e. 2^{16}). Setting up an AI block as in figure 4.19 (i.e. WEIGHT1) which gets data from the register I:011 completes the *reading the*

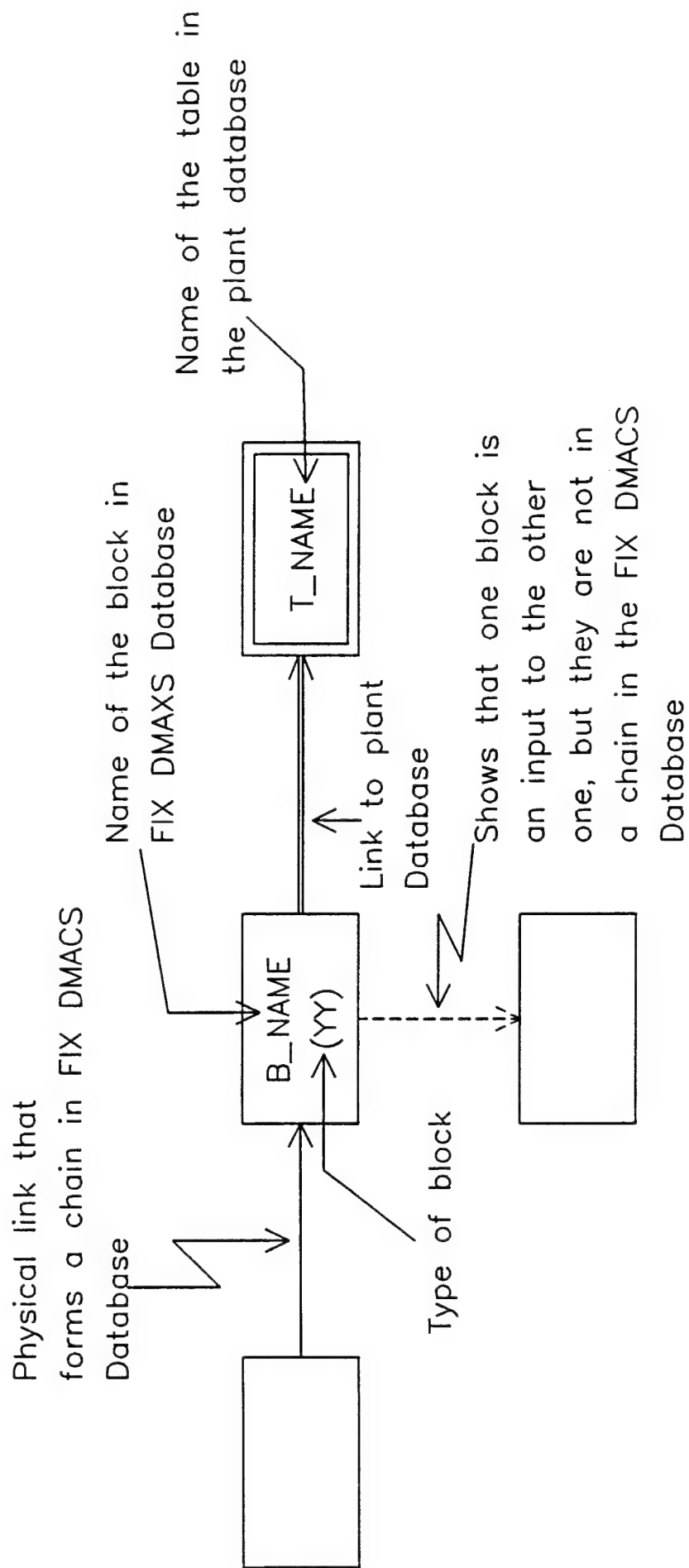


FIGURE 4.1: LEGEND FOR DATABASE BLOCK RELATIONS

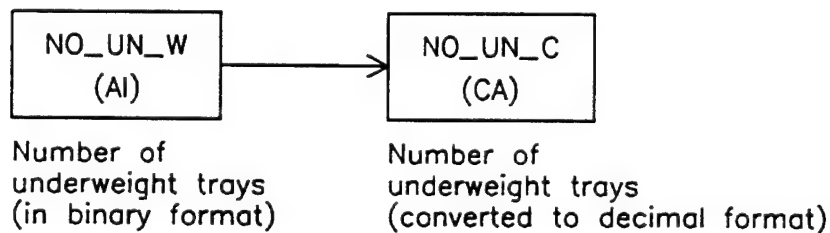
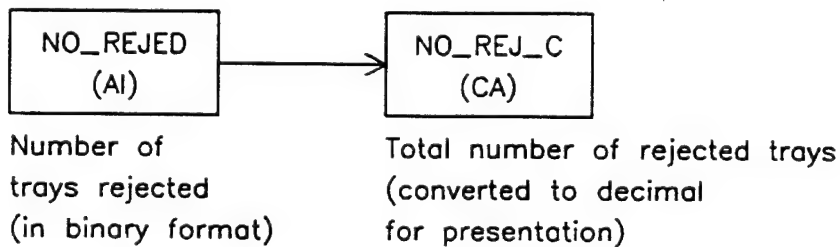
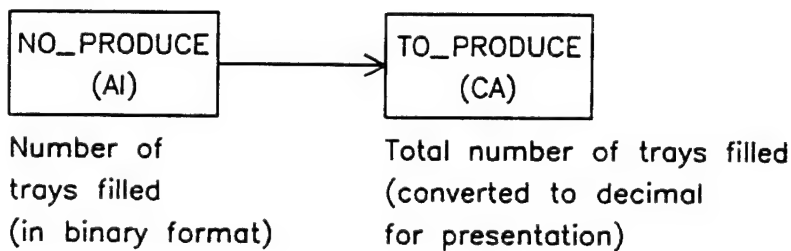
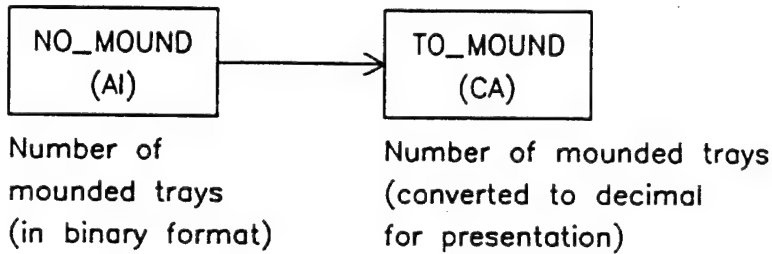
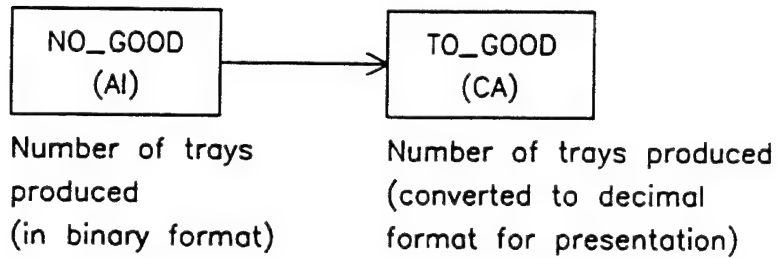
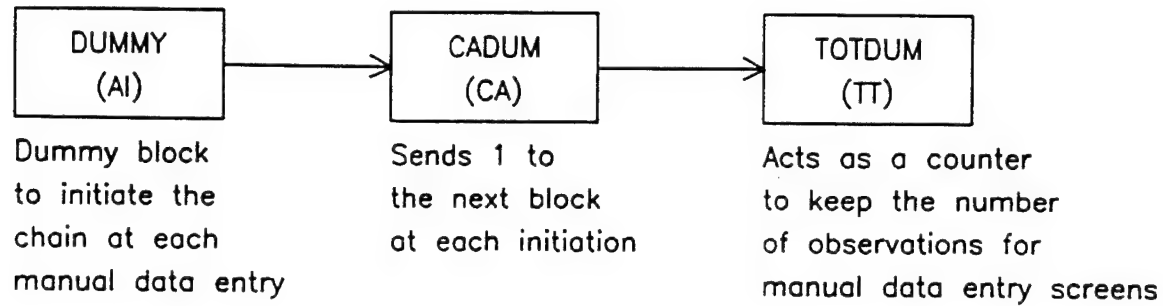


FIGURE 4.2: LINE PERFORMANCE

data from PLC part of the activity. In this block's set up, the mode is set to automatic and the scan time is set to 1 seconds. This means that the register is scanned every second automatically. However, this raw data cannot be used in the format it is acquired from the PLC. It has to be converted into decimal format for further use. Hence the block, WEIGHT1, is then chained to the CA block W1 through its *next block* definition. Each 4-bit set of numbers correspond to a place in decimal format. Hence we need 4 AI blocks to be chained to 4 CA blocks each of which is responsible for the calculation of a certain place in the decimal format. W1 is the CA block that's responsible for only calculating the hundreds place in the converted value. For the rest of the BCD to decimal conversion, W2, W3 and W4 are used to calculate the tens, ones and decimal places of the weight, respectively.

Analog Input Block

Tag Name: **WEIGHT1** Next Block: **W1**

Description: **BCD Reading from the PLC**

☒ Start Block On Scan

Scan Time: **1**

Smoothing: **0**

Hardware Specifications

Device: **ABK**

Hardware Options:

I/O Address: **PLC5:I:11**

Signal Conditioning: **NONE**

Engineering Units

Low Limit: **0.00**

High Limit: **9,000.00**

Units:

Initial Mode

☒ Automatic ☐ Manual

Alarms

☐ Enable Alarming

Alarm Areas: **ALL**

Low Low: **0.00**

Low: **0.00**

High: **9,000.00**

High High: **9,000.00**

Rate of Change: **0.00**

Dead Band: **450.00**

Priority

☒ Low ☐ Medium ☐ High

Security Areas

1: **NONE**

2: **NONE**

3: **NONE**

OK Cancel Help

Figure 4.19: AI Block to read BCD data from PLC 5/12

W1 is chained to another CA block, W_TOTAL where all the other 3 CA blocks are viewed as inputs. Note that no more than one block is allowed to be an upstream block in a chain. In W_TOTAL, the values that are carried by W1, W2, W3 and W4 are used to calculate the actual weight of the tray in decimal format. Refer to figure 4.20 for an illustration of a typical CA block (i.e. W_TOTAL)

Calculation Block

Tag Name: **W_TOTAL** Next Block:

Description: **Actual weight value of the tray**

Inputs		Engineering Units	
A:	Previous Block	Low Limit:	0
B:	W2.F_CV	High Limit:	1,000
C:	W3.F_CV	Units:	<input type="text"/>
D:	W4.F_CV		
E:	100	Alarms	
F:	10	<input type="checkbox"/> Enable Alarming	
G:	<input type="text"/>	Alarm Areas: ALL	
H:	<input type="text"/>	Security Areas	
		1:	NONE
		2:	NONE
		3:	NONE

Use terms A through H in the output calculation.

Output Calculation: **(((A*E)+(B*F))+C)+(D/F)**

OK **Cancel** **Help**

Figure 4:20: Final Calculation Block in the Chain of BCD to Decimal conversion

One other block which is commonly used for data processing in Tray Pack line implementation is the SD block. As described above the weight of every single tray can be obtained

from the line and converted into a desirable format. It is likely to collect more than 10 data points for tray weights per minute in a normal speed of the line. Therefore, if every single weight is stored in a file or a table, big memory space will be required. Furthermore, nobody would really be interested in the weights of every single tray produced, provided that they are within a specified range. Therefore it is more desirable to make use of average weights over a time frame or the number of trays. This type of data manipulation is performed through the SD block.

In the example of figure 4.3, the weight of each individual tray is infed to W_STAT where statistical calculations, such as average, standard deviation and range of weights over a specified number of observations, are performed. Refer to Figure 4.21 for a typical SD block setup. According to the setup in figure 4.21, the processor automatically checks the *input* block (i.e. W_TOTAL) every second to grab a data point. If no *scan qualifier* is specified then the SD block grabs whatever data is available in its input block at the time of the scan. This may cause error in application since the data may not have been updated in the input block yet. In this example, TRAY_READY is a DI block (physically, it's a sensor on the line) which signals to W_STAT when there is a new tray on the Check weigher. In this case, W_STAT will take the value calculated in W_TOTAL only when it receives a signal from TRAY_READY block.

In figure 4.21, *observation/group (n)* refers to the sample size that the statistics will be performed on. Average, standard deviation and range of weights will be calculated using this value (i.e., 5 in this case). The minimum and maximum allowable numbers are 1 and 25 respectively. If a grand average, such as \bar{x} , is required then the calculations will be based on *number of observations*, as well. The minimum and maximum allowable entry for *number of observations (N)* is 12 and 50, respectively. As can be seen, SD block samples on count rather than time basis. That is, we can get a data after certain number of trays are weighed rather than a certain time has elapsed. But if the line speed is known, it can also be interpreted on the time basis by adjusting the entries for observation/group and number of observations. It is also possible to specify some alarm specifics through a SD block. But this will be discussed later in section 6.

Statistical Data Block

Tag Name: Next Block:

Description:

☒ Start Block On Scan

Scan Time:

Statistical Data Specifics

Scan Qualifier:

Input Tag:

Number of Groups:

Observations/Group:

Wait Time:

Initial Mode

☒ Automatic ☐ Manual

Auto Limits

☒ Startup ☐ Always ☐ Never

Auto Calculations

☒ Startup ☐ Always ☐ Never

Engineering Units

Low Limit:

High Limit:

Units:

Security Areas

1:

2:

3:

Figure 4.21: Statistical Data Block to perform statistical Calculations on Tray Weights

Through the use of CA and SD blocks, data is processed and converted into a desirable format. This concludes the *data manipulation* stage. Some other blocks, like PG and BL blocks, are also used for data manipulation.

It is possible to display the raw or processed data through the *data links* provided in *View* application of FIX DMACS. For instance, statistical charts like Xbar, Sbar and Rbar charts are available for the illustration of a SD block. We designed a “Charts Screen” so that the operator can view the average, standard deviation and range of tray weights for specified sample size ($n=5$ in this case) through some statistical charts. Display development will be discussed more in the next

section. The reason why we mention the operator interface design here is to emphasize that any data we gather will be used in the supervision of the Tray Pack line.

Since we acquire the real-time data, any change that occurs in the line will result in an update on the operator screens and the previous data will be lost unless stored in a database. For further use, certain data points are sent to the plant database and stored in Oracle forms. Mainly three types of data are sent to the plant database;

1. Operator information:

Operator ID numbers and comments are entered manually by the operator at the beginning of each shift and this information is sent to the plant database together with a time stamp. This data can be used by the management to keep track of the shifts and operators

2. Process and Sampled data;

i) Average weight for filled and accepted trays; This data is sent automatically together with a time stamp for every specified number of trays.

ii) Samples from Solbern and Oden fillers; Every 15 minutes the operator takes sample weights from these two fillers and enters them manually through the operator screens. Average of the samples with a time stamp are then sent to the related tables in the plant database.

This type of data can be used for some statistical analysis and quality control purposes.

3. Material Tracking data: ID's of all the materials used in the production of a certain batch are entered by the operator. Beef, gravy, can and lid lot id's are then sent to the plant database together with the start time of each lot. These are the main raw materials for the Tray Pack line. After being sealed the trays are sent to the retort. Retort crate id's and start time for the filling of that crate are also sent to the plant database. In case of any problem in the process, each material can be traced back for a specified batch produced by looking at the stored data.

Type of data and SQL table names where each data is stored are shown in figures 4.2 through 4.18.

There are two blocks related with the data transfer to and from the plant database; SQT and SQD. The set up of SQT and SQD blocks are very similar for all of the above data types. Therefore we will be giving only one example for each. SQT block checks for certain events to be satisfied and once these conditions are true it triggers the related SQD block. Note that an SQT block is always chained to an SQD block. In figure 4.22, we see the SQT block built to send the average tray weight

to the plant database. The condition in this case is the *change of the average of the tray weights* as calculated in the SD block W_STAT. Once W_STAT's output changes, AVG_TRI triggers its next block, AVG_DATA, automatically. If the SQT block is set to *manual*, which is the case in material tracking data, the block has to be triggered manually from the operator screen through some push buttons.

The other important entry in the definition of an SQT block is the SQL name. When AVG_TRI is triggered there is a SQL command which is executed. This command is called by an SQL name (i.e. AVGINS in this example) in FIX DMACS.

To construct the link between the SQL name and the actual SQL command, we create a library table, SQLLIB, in SQL Plus. This table consists of two columns; the first one contains the SQL names as referenced in FIX DMACS and the second column contains the corresponding SQL command which will be executed upon the triggering of the SQT block. In the case of average weights of the trays, when AVG_TRI is triggered, SQLLIB is searched to locate the name AVGINS. When AVGINS is found the corresponding SQL command from the second column, "*insert into average_weight (average_weight, tmdt) values (?,?)*", is executed.

The SQD block, (AGV_DATA in this example), is responsible for keeping tagnames (W_STAT in this case) of the data that will be transferred and the direction of the transfer. That is, the question marks in the above command are replaced by the values in the specified block in the SQD. For the direction of the transfer OUT means the data is sent to and IN means the data is received from the plant database. Refer to figure 4.23.

SQL Trigger Block

Tag Name: Next Block:

Description:

☒ Start Block On Scan SQL Name:

Scan Time:

Initial Mode
☒ Automatic ☐ Manual

Date Filters
Start Date:
End Date:

Time Events
Start Time:
End Time:
Event Period:

☒ Enable Backup

Block Events
Event Type
☒ Change of Value
☐ Low to High
☐ High to Low

Event Tag:

Confirm Tag:

Figure 4.22: SQT Block to send average weight of trays to plant database

exception based because the schedule or the set points for the system does not change as often as the tray weights. Therefore to have an efficient FIX DMACS database it is better to have “exception based” polling when the event changes are sporadic, or else set the block on automatic scan for frequently changing events.

SQL Trigger Block

Tag Name: Next Block:

Description:

☐ Start Block On Scan SQL Name:

Scan Time:

Initial Mode: ☒ Automatic ☐ Manual

☒ Enable Backup

Date Filters: Start Date: End Date:

Time Events: Start Time: End Time: Event Period:

Block Events: Event Type: ☒ Change of Value ☐ Low to High ☐ High to Low

Event Tag:

Confirm Tag:

Figure 4.24: SQT block to receive process parameters

For SQD block, the only change in the set up is with the direction. Since now we will be receiving data from the plant database, the direction is written as IN. Refer to figures 4.24 and 4.25 for the SQT and SQD set ups for receiving tray weight parameters from the database.

SQL Data Block			
Tag Name:	DATA_PARAM	Next Block:	
Description:	Process parameters from schedule in DB		
Security Areas		Alarm Areas: ALL	
1:	NONE		
2:	NONE		
3:	NONE		
Tag.Field	Direction	Reset to:	
W_STAT.A_NGRP	IN	NONE	
W_STAT.A_NOBS	IN	NONE	
W_STAT.F_USLX	IN	NONE	
W_STAT.F_LSLX	IN	NONE	
W_STAT.F_UCLR	IN	NONE	
W_STAT.F_LCLR	IN	NONE	
	OUT	NONE	
	OUT	NONE	
	OUT	NONE	
More Entries...		OK	Cancel
		Help	

Figure 4.25: SQD block to receive process parameter from database

There are other blocks that we used to build the FIX DMACS database for data acquisition and operator interface designs. Above, we described only those which we utilize frequently. For more details on Database Builder and functions of other blocks, refer to *Intellution Database Builder Manual*.

5. Display Development

In this section we will describe the operator screens that we designed to view the Tray Pack line. *Draw* is the application used to create the pictures and *View* is the application to view the picture with real-time data. Due to the limitation of space and time we will not describe how each picture is created. We would rather provide a *Manual* here, which describes how to use the operator displays. For further information on creating pictures, refer to *Intellution Draw Manual*.

We designed 10 displays to view the Tray Pack line, enter sample data manually, receive schedule and set points from the plant database. Operator screens, the access links between them, file names as saved in *draw* program are given in figure 5.1. The figures 5.2 through 5.11 show the individual picture for each of the operator screens.

5.1. Manual for Tray Pack Line Operator Screens:

The designed operator screens for Tray Pack line are very user friendly. The operations are mostly self explanatory. For those which may create confusions we tried to provide messages to lead the operator. To clear further difficulties, we will go through each screen in this subsection.

At the beginning of each shift, the first screen is the *Operator Login Screen*. Refer to figure 5.2. The operator has to enter Operator ID and any comments to be made at the beginning of the shift. Upon pressing the ENTER button, a *command language* code is executed. The command language is a FIX DMACS scripting tool that lets the designer to automate operator tasks through a series of instructions. Command language scripts store these instructions within a series of commands and parameters. Then FIX DMACS executes the instructions upon request from View, like pushing the ENTER button in this case. Command Language can be used to manipulate files, manage alarming, control database blocks, run other applications automatically, incorporate custom security features and to design custom prompts and messages for the operator. In all of the push buttons created in the pictures for Tray Pack line we used the command language to achieve some of the tasks listed above. For more information on the command language refer to *Intellution Command Language Manual*.

Through the code embedded in the ENTER button in *Operator Login Screen*, the information entered by the operator is saved in the plant database together with a time stamp and a new picture

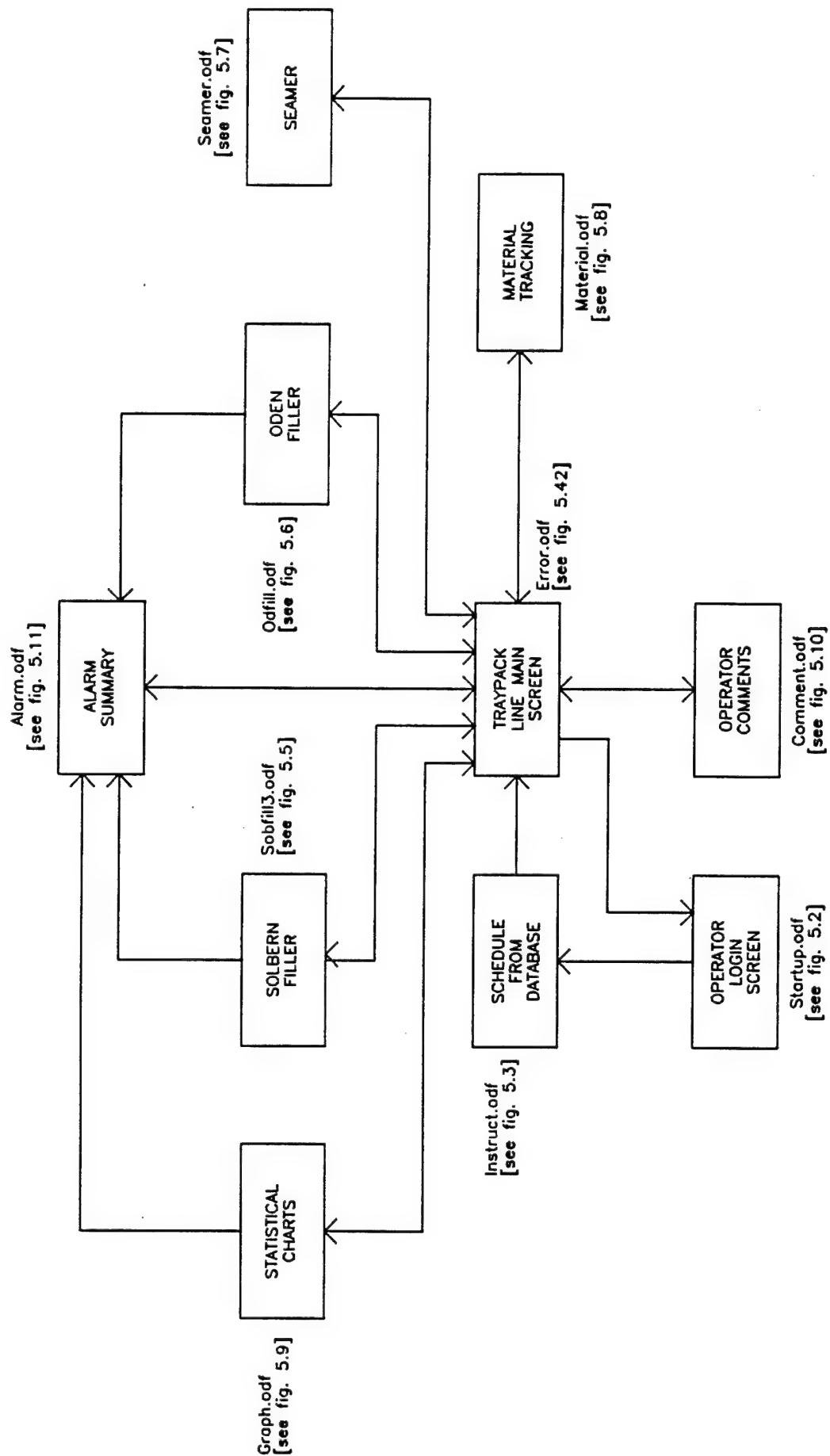


FIGURE 5.1: CONNECTION BETWEEN TRAYPACK LINE OPERATOR SCREENS

(Note: *.odf = filename in draw application)

Intellution FIX View

FileViewAlarmsCommandsApplicationsOptionsHelp

Date:3/31/95

Time:4:11:39 PM

Operator ID:OPER25

Comments:NORMAL RUNNING CONDITIONS

ENTER

FIGURE 5.2: Operator Login Screen

SCHEDULE FROM DATA BASE:

❗ Please Check All the Settings of the Line and Make the Necessary Changes as Specified by the Schedule

PLC Settings:

Product Type: DESSERT

No. to Produce: 300.00 trays

Production Rate: 10.0 trays / min.

Checkweigher Settings:

Weight Xbar Upper Spec Limit: 30.00

Weight Xbar Lower Spec Limit: 25.00

Special Instructions: USE STRAWBERRY TOPPING

CONTINUE

FIGURE 5.3: Schedule From Plant Database

appears on the screen. This is the *Schedule From Database* screen. Refer to figure 5.3. The reader should note that the command language in *Login* screen has an instruction to trigger the related SQT block to transfer the schedule data from the plant database. Therefore once the screen changes from *Login* to the *Schedule*, we will have the information ready for the operator.

The PLC code for the Tray Pack line requires that some of the settings, like production rate, has to be entered manually through a control panel on the PLC. Similarly, Check weigher has to be setup manually for the correct product weight target value, upper and lower control limits. Hence the operator has to check certain settings of PLC and the check weigher as described on the *Schedule* screen and make necessary changes manually before starting the line. More information from plant database can be provided to the operator when the schedule tables are completed in Oracle. The operator must push the CONTINUE button after checking and correcting the required settings. Upon pressing the button, a message appears to remind the operator once more to check the PLC and Check weigher settings if it hasn't been done yet. The operator confirms and the screen changes to the *Tray Pack Line Main* screen.

The figure 5.4a depicts the main screen to view the Tray Pack line as seen in *View*. To give more insight to some of the design issues we also include the *Main screen as designed in Draw* by figure 5.4b. The reader will immediately realize that, depending on the real time data and the dynamic attributes of the objects, the screen in *view* will be a window to the Tray Pack line. All the other screens can be accessed from this screen. The *Main* screen has the following features;

a) It displays a line drawing of the Tray Pack line. Since the information received from PLC is not sufficient, a real time simulation of the process cannot be provided. Only when the tray reaches the diverter, the operator receives an input from the PLC (i.e. whether the tray is accepted or rejected). On the *Main* screen, a blue box passing the diverter represents an accepted tray and a red box diverted to the reject lane represents a rejected tray.

b) It displays the type and place of the problem when a fault appears in the Tray Pack line. FIX DMACS provides the user with the ability of alarming in case of a problem. Together with this feature, we designed the display such that each fault condition is hidden in the *Main* screen. That is, when an error occurs in the process, a message in red will appear on the *Main* screen identifying the cause and the place of the error. This message will stay until the problem is solved and normal

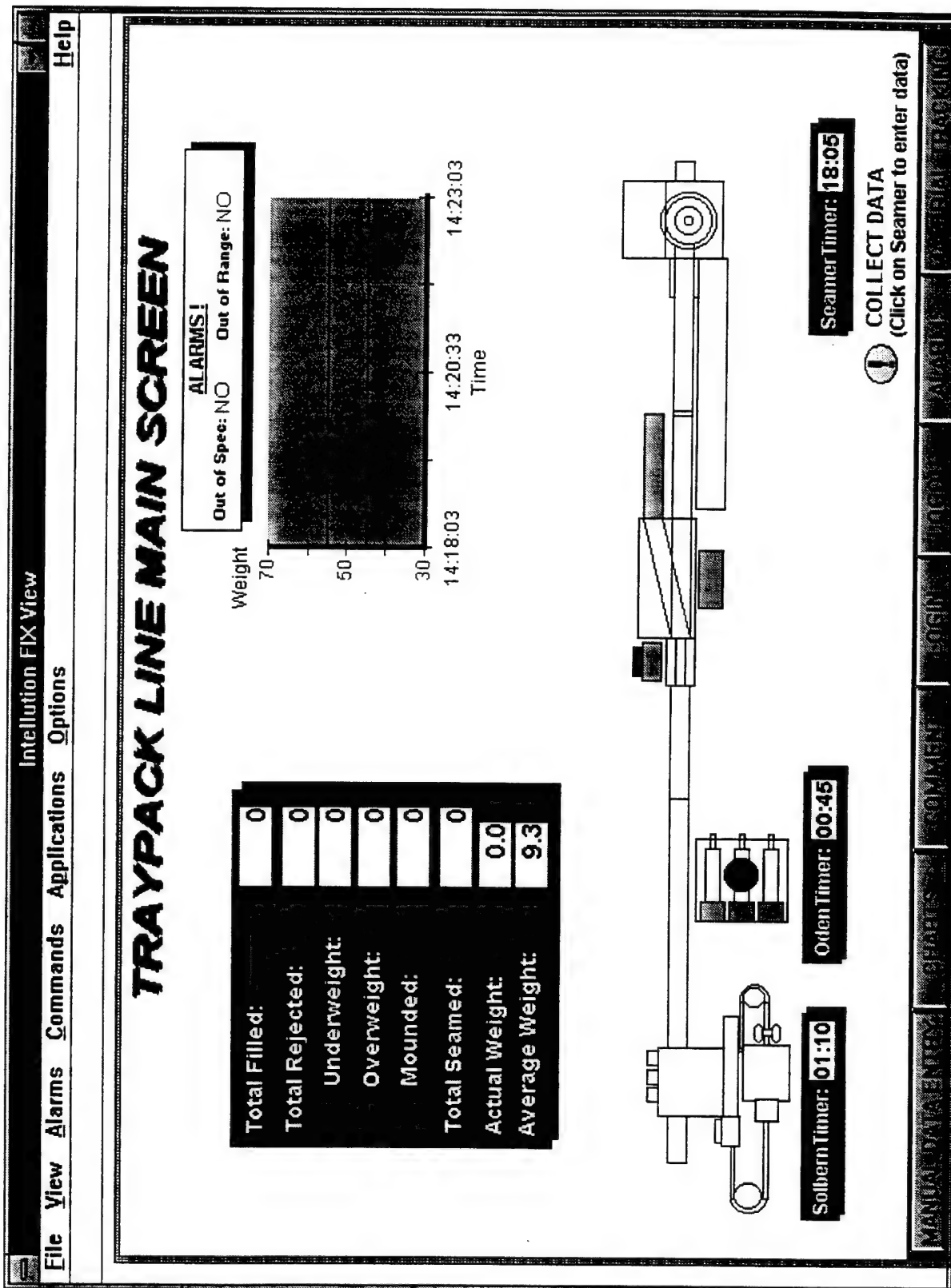


FIGURE 5.4a: Traypack Line Main Screen as seen in View

TRAYPACK LINE MAIN SCREEN

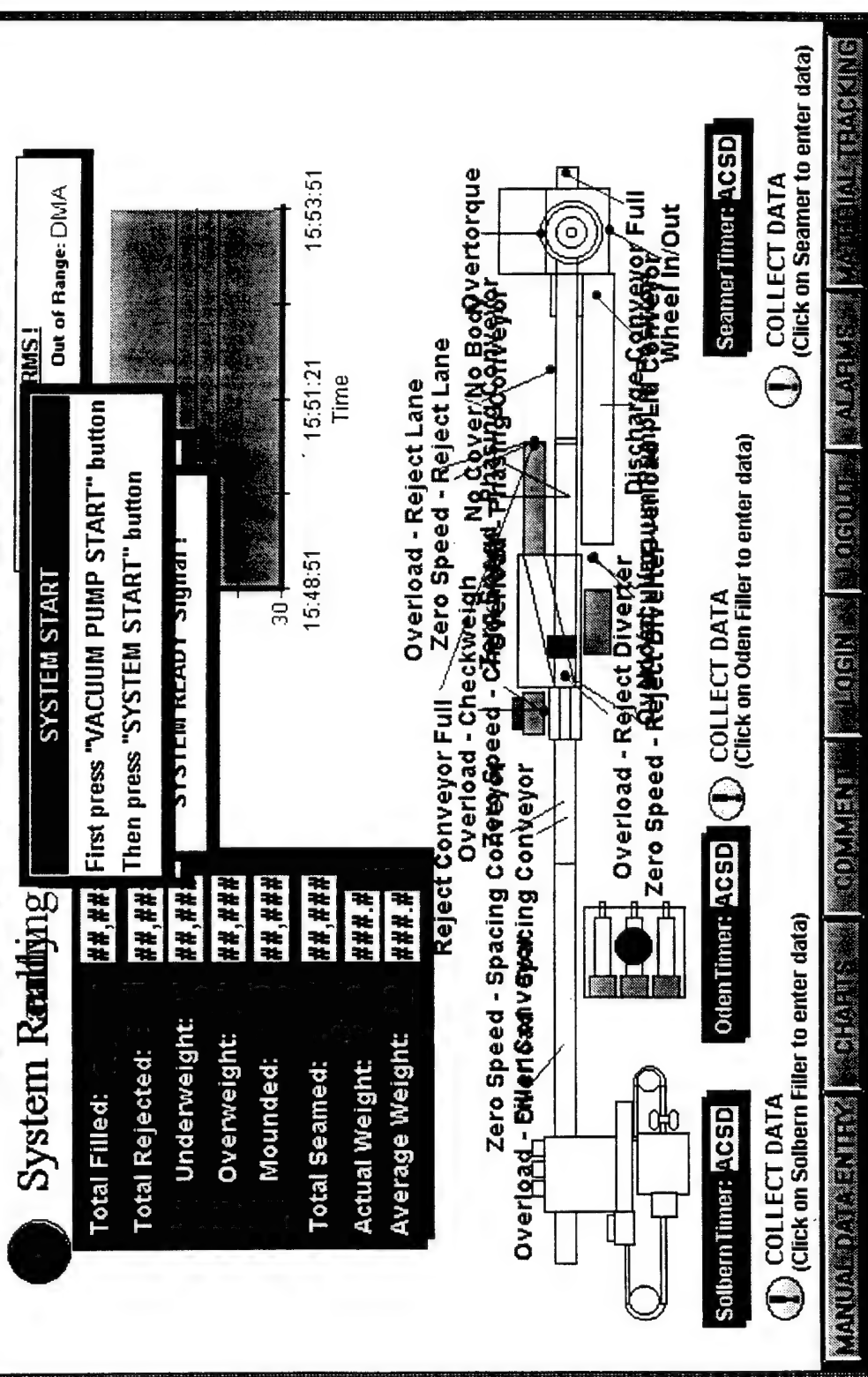


FIGURE 5.4b: Traypack Line Main Screen design as seen in Draw

operation conditions are recovered.

c) It describes the steps to start the system from the PLC panel. If the system hasn't started yet, a message will appear on the *Main* screen to instruct the operator on how to start the system.

d) It displays the status of the system. There are three different states of the system shown on the upper left corner of the screen: System Ready (shown in blue), System Running (in green) and System Fault (in red). System is ready if no error conditions are present and the MCR button is pressed. If MCR button is not pressed the operator will be prompted to do so before starting the system. System is in Running status when all the operations are performed without any fault. And System Fault signal appears in case of an error as described in part b.

e) It displays some performance measures related with the production. For the time being, the measures are limited to the count of trays; total number of trays filled, produced, rejected (rejection causes categorized as underweight, overweight and mounding) and weight (i.e. actual and average) of filled trays. A table which contains the real time data from the line is displayed on the *Main* screen for this purpose.

f) It displays a chart to show the trend of the tray weights. More statistical charts on tray weights are provided but this trending chart provides a visual tool to show the behavior of the tray weights over a time range of 5 minutes.

g) It provides the operator with the data sampling timers. Every 15 minutes, the operator or a quality control staff is required to take samples, such as beef weights, sauce temperature, ...etc., from the Solbern Filler, Oden filler and the Seamer. We designed three independent timers for each of these machines. These timers start automatically at the beginning of the shift, warns the operator to collect data from a given machine. When the timer reaches 15 minutes, the color of timer box turns to red, a written message appears and audio signal is provided in case the horn is enabled. Refer to seamer timer in figure 5.7. The written message directs the operator to the next screen where the sample data is entered. By clicking on the specified machine, the operator will switch to another screen (i.e. *Solbern Filler*, *Oden Filler* or *Seamer* screens) where the operator enters the sample data.

In *Solbern Filler* screen (see figure 5.5), the operator is supposed to enter sample beef weights and the beef temperature. Right now the set up is such that the operator can change the

SOLBERN FILLER

XBAR CHART PARAMETERS

Number of observations:
(per group)

Upper Spec Limit:

Lower Spec Limit:

1

55.00

45.00

XBAR CHART

Sample	Weight
0	55.0
1	55.0
2	55.0
3	55.0
4	55.0
5	55.0
6	55.0
7	55.0
8	55.0
9	55.0
10	55.0
11	55.0
12	55.0
13	55.0
14	55.0
15	55.0
16	55.0
17	55.0
18	55.0
19	55.0
20	55.0
21	55.0
22	55.0
23	55.0
24	55.0
25	55.0
26	55.0
27	55.0
28	55.0
29	55.0
30	55.0
31	55.0
32	55.0
33	55.0
34	55.0
35	55.0
36	55.0
37	55.0
38	55.0
39	55.0
40	55.0
41	55.0
42	55.0
43	55.0
44	55.0
45	55.0
46	55.0
47	55.0
48	55.0
49	55.0
50	55.0

Accepted Weight :

ENTRY

R CHART

Sample	Weight
0	0
17	0
33	0
50	0

Beef Temperature: 76.30

SAVE

ALARMS!	
Out of specification limits:	YES
Trend of runs:	NO
Alarm Summary	

Press "RETURN and RESET"
to Return to Main Screen and Reset the Solbern Timer

Press "CANCEL"
just to Return to Main Screen

FIGURE 5.5: Solbern Filler Screen

ODEN FILLER

<p style="text-align: center;">XBAR CHART PARAMETERS</p> <p>Number of observations: <input style="width: 50px;" type="text" value="2"/> (per group)</p> <p>Upper Spec Limit: <input style="width: 50px;" type="text" value="50.00"/> Lower Spec Limit: <input style="width: 50px;" type="text" value="45.00"/></p>	<p style="text-align: center;">XBAR CHART</p>
<p style="text-align: center;">Accepted Weight : <input style="width: 50px;" type="text" value="47.24"/></p> <p style="text-align: center;">ENTRY</p>	<p style="text-align: center;">R CHART</p>
<p style="text-align: center;">Sauce Temperature: <input style="width: 50px;" type="text" value="25.50"/></p> <p style="text-align: center;">SAVE</p>	<p style="text-align: center;">ALARMS!</p> <p>Out of specification limits: NO Trend of runs: NO</p> <p style="text-align: center;">Alarm Summary</p>

Press "RETURN and RESET" to Return to Main Screen and Reset the Solbern Timer

Press "CANCEL" just to Return to Main Screen

FIGURE 5.6: Oden Filler Screen

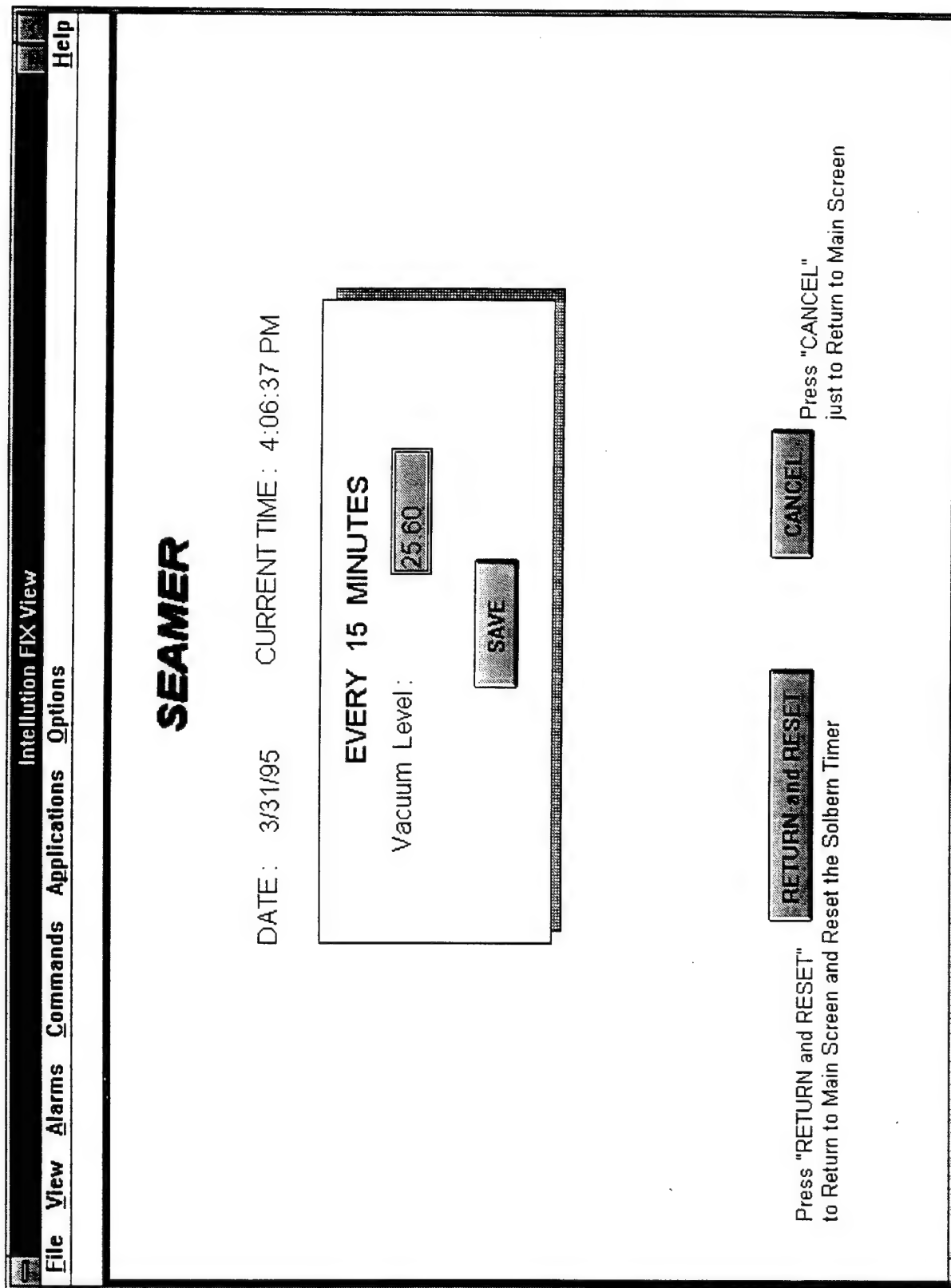


FIGURE 5.7: Seamer Screen

number of observations for the beef weight sample. How to limit the access to some applications and fields will be discussed in section 7 and the setup in the *Solbern* screen can be modified to secure certain parameter fields, such as the number of observations accordingly. To enter the sample beef weights, the operator clicks on the ENTRY button. Then, the operator is prompted to enter the weight as many times as the number of observations, n . After n data points are entered, the average is plotted on an x-bar chart, r-chart is updated and the processed data (average weight, R,...etc.) is sent to the plant database. If the operator has more sets of data, the same instructions are followed again. As for beef temperature, the operator should select the gray box, enter the data and click on SAVE button to send the data to plant database.

Once the data entry is over, by clicking on the RESET and RETURN button, the timer for *Solbern* will automatically be initialized and the screen will switch back to the *Main* screen. We also have a CANCEL button which enables us to switch between the two screens (*Main* and *Solbern Filler*) without resetting the timer.

Oden Filler (figure 5.6) is almost identical and the instructions to enter the sample data is the same. As for the *Seamer* (figure 5.7) screen, the only sample data required is the “vacuum level” and the instructions are identical with the “beef “ and “sauce” temperatures in *Solbern* and *Oden fillers*, respectively.

h) The main screen provides access to other screens through push buttons on the bottom of the screen. *Solbern Filler*, *Oden Filler* and *Seamer* screens and the link to them from the *Main* screen are already discussed. One can also access to these three screens by clicking on the MANUAL DATA ENTRY button.

In food manufacturing, it is very important to keep track of the material used so that in case of a low product quality or some other problems and complaints, all materials used in the production of that production batch can be traced. We provide a *Material Tracking* screen for the Tray Pack line. Refer to figure 5.8. Current setup requires that the operator enters the lot id's and start time of the material lot manually. Through the data entry process, the operator will be prompted on what is required at each step. For example, if the operator wants to report on the material “can”, press the arrow on CANS line. First the lot id and then the start time of that particular lot will be requested. The data entered will appear on screen to check. If any mistake is made, same procedure can be

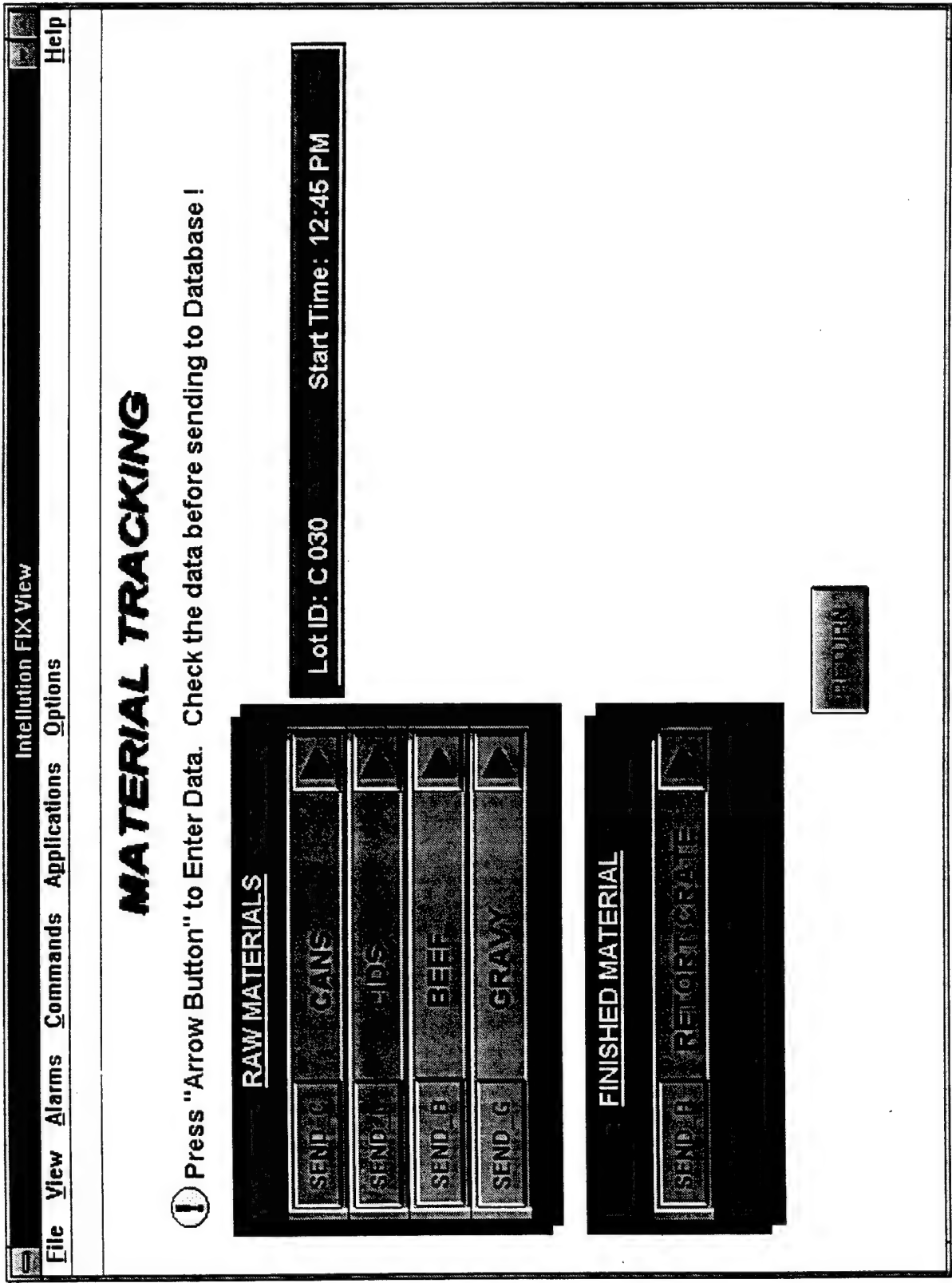


FIGURE 5.8: Material Tracking Screen

repeated before sending the data to the plant data base. The operator will then be prompted to press SEND_C to send the data to the plant database. A message will appear when the data transfer is complete. The other main materials used are lids, beef and gravy and the procedure to follow is the same. The produced trays can also be registered through this screen (i.e. retort crates) before being processed in the retort. RETURN button switches the screen back to the *Main* screen.

The *Statistical Charts* screen (figure 5.9) provides the Xbar and Rbar charts for the tray weights that are recorded from the Tray Pack line. The control chart parameters shown are transferred from the plant database. Two types of alarms are specified for the tray weights; *out of specification* and *out of range*. If violation of these rules is detected, NO's will be replaced for YES in the Alarms box. This screen can be accessed from the *main* screen by clicking on the CHARTS button.

At any point during the shift, the operator might make some comments about the process or the machines. These comments will be sent to the plant database together with a time stamp. This can be done by clicking on the COMMENT button from the *Main* screen. Refer to figure 5.10 for an illustration of the *Operator Comments* screen. The operator should select the gray box, enter the time and then comments. If SAVE and RETURN is pressed the comments will be transferred to the database and screen will change to *Main* screen. CANCEL button will only switch the screen back to the *Main* screen.

A summary on the alarms that have occurred during production can be viewed from the *Alarm Summary* screen (figure 5.11). This screen can be accessed from *Main* screen by clicking on ALARMS button or from *Statistical Charts*, *Oden Filler* or *Solbern Filler* screens by clicking on ALARM SUMMARY button. Depending on the importance of the error (i.e. priority) the alarms are classified as; Low, Medium and High. Low alarms are assigned pink color on the *Alarms Summary* screen. Similarly, medium and high alarms are assigned bright red and dark red colors, respectively. For each alarm, the block's tag name, the description of the block, first time and the last time of alarming, status and the value (where applicable) of the alarming block are provided. The operator may add more information, or change the current column setting by clicking on COLUMN button from *View*. It is possible to filter the alarms according to their classes and alarm areas. This way, only certain alarms will be listed. For the time being the filter is set in such a way that all the

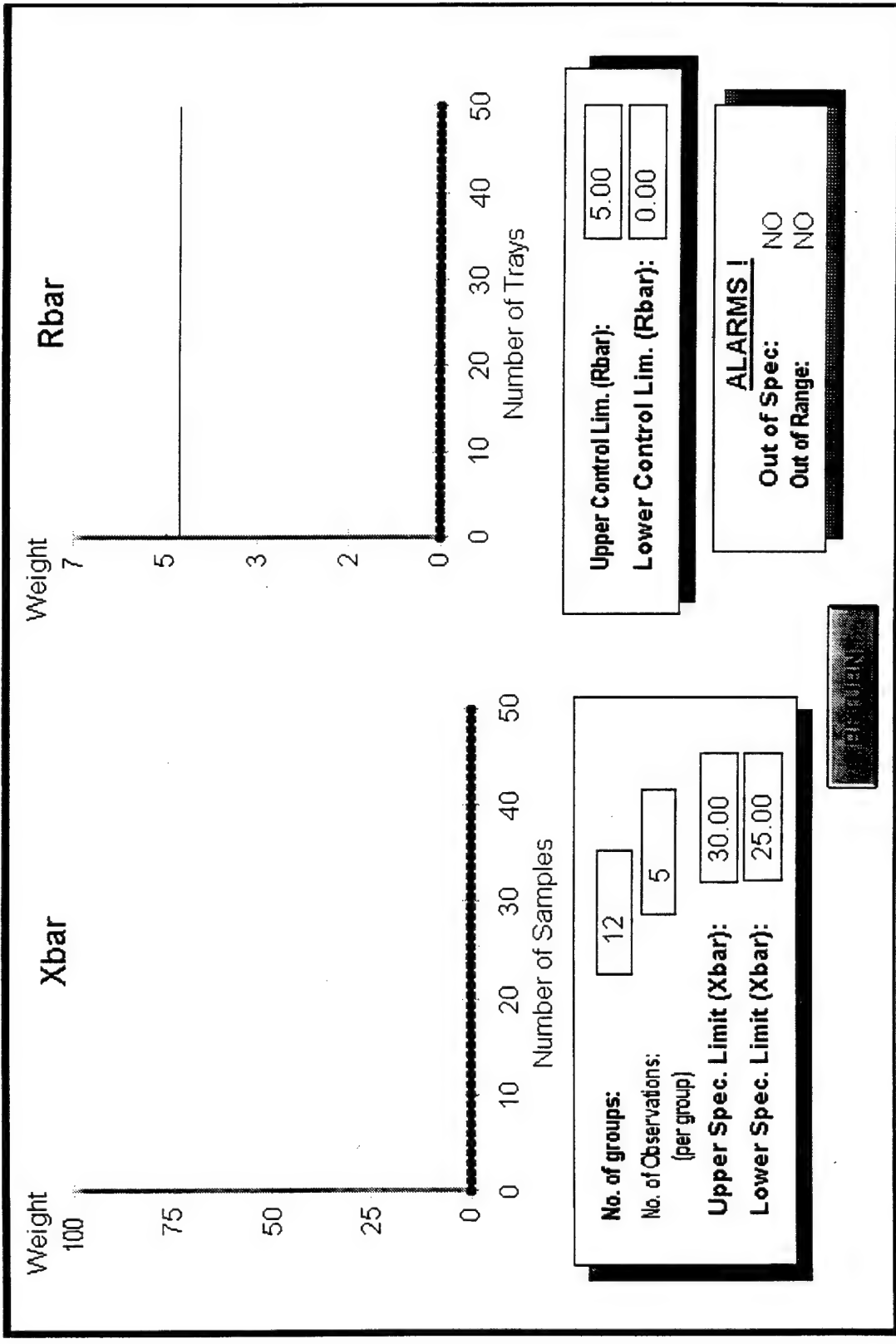


FIGURE 5.9: Statistical Charts

OPERATOR COMMENTS

DATE: 3/31/95 TIME: 3:52:05 PM

OCCURENCE TIME: 3:45 PM

OPERATOR COMMENTS:

OVER LOAD IN SPACING CONVEYOR

SAVE AND RETURN

CANCEL

FIGURE 5.10: Operator Comments Screen

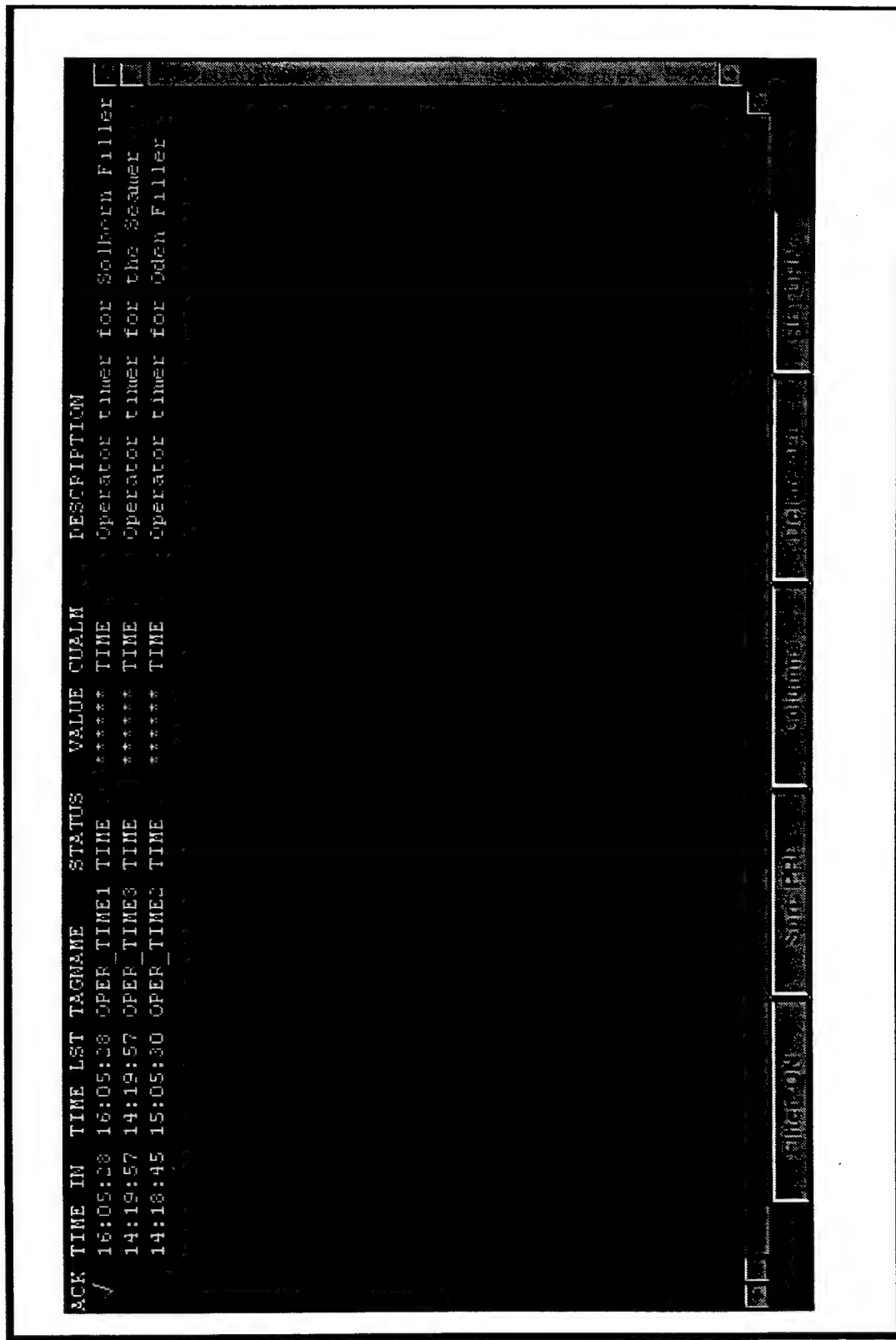


FIGURE 5.11: Alarm Summary Screen

alarms from all the areas are listed on the screen, ordered by their priority. It is possible to change the filter setup by clicking on FILTER button. The alarms can also be ordered in different ways. To change the order of the listed alarms click on SORT button and select the desired sorting rule from the dialog box. By double clicking on a certain entry on the screen the operator can acknowledge the alarm. A check mark will appear next to the acknowledged entry, the status of the block turns to OK and the horn will be disabled. Clicking on DELETE ALL button will erase all the alarms listed. RETURN button will take the operator back to the *Main* screen.

6. Alarming and Messaging

FIX DMACS defines *alarms* as a block condition indicating that a process value has crossed a predefined limit and requires a response. Database alarms provide operator with important information about process values at their monitor. Alarms also require operators to examine this information because the alarms stay on the monitor until the operator acknowledges them. Finally alarms can automatically initiate a process sequence when an alarms occurs. This final feature of alarms hasn't been implemented for the Tray Pack line yet.

The type of alarming that is implemented in the Tray Pack line can be classified into two groups; the standard alarming that uses standard FIX DMACS alarming tools and the designer defined alarming. By the first group, we refer to those alarms that can be set up using the database block's alarming features. These alarms are viewed in *Alarm Summary* screen as explained in the previous section. All of the blocks have alarm setting fields. We enabled alarming for certain blocks that are crucial in the process, like the SYS_FAULT block as shown in figure 6.1. For some other block, like an intermediate calculation block, the alarming is disabled for efficiency purposes. Refer to figure 6.1 for a typical Alarm field in a DI block. This particular set up will enable an alarm (such as a horn and an entry in the alarm summary link) with high priority when the value of that digital block changes. That is, when a fault in the system occurs.

By the second group of alarms, we refer to the alarms custom designed for the operator screens, like *main screen*. The system fault conditions which are described in the previous section

are examples to this group. In this type of alarms, we used the object links and dynamic property attributes that are provided in *Draw* program. According to the real time data, these alarms will appear or disappear on operator's monitor.

Digital Input Block

Tag Name: Next Block:

Description:

Hardware Specifications

Device:

Hardware Options:

I/O Address:

Initial Mode

☒ Automatic ☐ Manual

☒ Start Block On Scan

Scan Time:

☐ Invert Output

Labels

Open:

Close:

Alarms

☒ Enable Alarming ☐ Event Msg

Alarm Areas:

Priority

☐ Low ☐ Medium ☒ High

Type

☐ Open ☒ Change of State

☐ Close ☐ None

Security Areas

1:

2:

3:

Figure 6.1: Alarm setup for SYS_FAULT block

As a part of the first group of alarms it is also possible to have alarms based on product specifics as opposed to process specifics. One of the blocks commonly used for this purpose is the SD block. For example; for the tray weights, two alarm types are chosen; *N point Specification Limit Alarm on XBAR* (with N=3) and *Trend of Runs Alarm* (with N=5). For W_STAT number of observations, N, is set to 12. This means among the 12 groups if any three of the group averages fall

off the specification limits then W_STAT will send an alarm to specified areas (in this case both to the SCADA and the view nodes). In the later alarm type, there will be an alarm if five consecutive groups out of 12 show a specific trend like monotonically increasing or decreasing values. Refer to figure 6.2 below. In this section we find it necessary to mention the alarm specifics of SD block, in particular, for the following reason:

Statistical Data Block (Page 2)

Tag Name: W_STAT

☒ **Enable Alarming**

Alarm Areas:

Alarm Priority

☐ Low

☐ Medium

☒ High

Enable Alarms	On Groups
<input type="checkbox"/> N Point Control Limit Alarm on XBAR	<input type="text" value="1"/>
<input type="checkbox"/> N Point Warning Limit Alarm on XBAR	<input type="text" value="3"/>
<input checked="" type="checkbox"/> N Point Specification Limit Alarm on XBAR	<input type="text" value="3"/>
<input type="checkbox"/> N Point Alarm on RBAR	<input type="text" value="1"/>
<input type="checkbox"/> N Point Alarm on SBAR	<input type="text" value="1"/>
<input checked="" type="checkbox"/> Trend of Runs Alarm	<input type="text" value="5"/>
<input type="checkbox"/> Length of Runs Alarm	<input type="text" value="7"/>
<input type="checkbox"/> N Point Critical Runs on XBAR	<input type="text" value="6"/>

OK Cancel Help

Figure 6.2 Alarm specifics for W_STAT.

As discussed earlier, SD blocks can be viewed through some statistical charts on operator displays. Given the above alarming option one would expect to see the alarm as soon as the condition occurs so that some further action can be taken, like stopping the line. In FIX DMACS, however, the SD block sends the alarm only after all the number of observations are completed. That is to say, the first 3 groups of weights are out of specification limits but W_STAT will alarm the operator only after all 12 groups (i.e. 60 trays) are weighed. In the mean time all 60 trays may be defective due to

a process error. The operator would have taken precautions if warned just after the first 3 groups are completed. Therefore, in practice this is not desirable and we believe that this should be pointed out to Intellution as well.

In FIX DMACS *messages* are defined as the system, database or operator information that does not require a response. There are three types of messages; event, system and operator messages. A list of system and operator messages together with the descriptions of each message are given in *Intellution Alarming and Messaging manual*. Event messages can be enabled through the alarms fields of the blocks, see figure 6.1. Similar to the alarming, we have custom designed messages as well. Once again, we use the *Command Language* and the *Draw* program features for the design of these messages. Figure 6.3a and 6.3b are examples of FIX DMACS application and custom designed messages, respectively. For further information on Alarming and Messaging, refer to the *Intellution Alarming and Messaging Manual*.

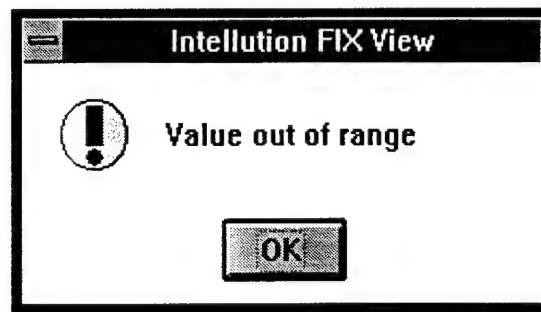


Figure 6.3a: Application message: manually entered data point was too big.

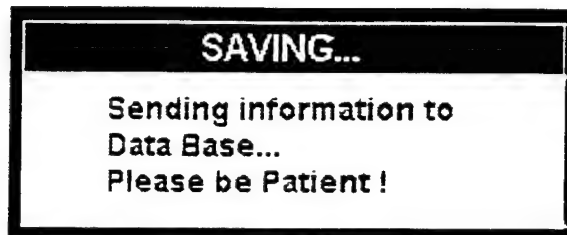


Figure 6.3b: Designed message: Sending data to plant database

7. Security

FIX DMACS is flexible enough to design a security system to protect the process. Through the security system, it is possible to limit the access of some users to certain applications of FIX DMACS, specific programs and operator displays. It further provides write protections for database blocks. The account privileges can be assigned through the *Security Configuration program* of FIX DMACS. In the Security Configuration Program there are two types of accounts;

a) Group Accounts: A group account assigns the most commonly used application features and security areas shared by two or more people. Once defined you can then assign a group account to individual users.

In Tray Pack line application we defined two group accounts: Supervisors and Operators. For each group, application features and security areas that are accessible by the group members should be defined through the Security Configuration Program. To give an example; for the group Operators, we assigned the applications View, Alarm Summary Display and Historical Trend Display to be accessible by the members of this group. Hence, they only have the privilege to use these tasks of FIX DMACS. No security areas are assigned for this group. A security area is a physical or functional division of the process. It's possible to have 256 security areas each of which is associated with a name up to 20 alphanumeric characters. The Group Supervisors are assigned the security areas A and B which are used in the FIX DMACS database. This means, the members of

the Supervisors have the privilege to *write* on the database blocks secured as the areas A and B, whereas the members of Operators Group cannot.

b) User accounts: This type of account defines the account privileges assigned to one person. Each user account is identified by a log in name and an optional password. Anyone requiring extra privileges beyond their group account can be assigned additional privileges. For example, it is possible to give access of a database block (secured as areas A or B) to a particular operator even though he/she belongs to the group Operators which does not have that privilege.

For the group and user account setups, refer to the *Security Configuration Program*.

8. Conclusion:

In this report we describe the FIX DMACS implementation to the Tray Pack line. The main aim is to acquire process data and monitor the system state. This document discusses certain features of the FIX DMACS in general, as well as how these features are utilized to collect, display and transfer data points from the Tray Pack line. Due to the limited space, we are unable to address each database block and display specific but plenty of examples are discussed to cover the most important data types and display techniques. We recommend that the reader refers to the FIX DMACS manuals, Tray Pack line database and the *.odf files for further information on the software, specific database block or chain setups and displays developed, respectively.

References:

1. ABK I/O Driver Manual, Intellution.
2. FIX DMACS Alarming and Messaging Manual, Intellution.
3. FIX DMACS Command Language Manual, Intellution.
4. FIX DMACS Data Base Builder Manual, Intellution.
5. FIX DMACS Database Reference Manual, Intellution.
6. FIX DMACS Draw Manual, Intellution.
7. FIX DMACS Real Time ODBC SQL Application Manual, Intellution.
8. FIX DMACS Security Manual, Intellution.
9. FIX DMACS DDE Support Manual, Intellution.
10. FIX DMACS System Configuration Manual, Intellution.
11. FIX DMACS View Manual, Intellution.

APPENDIX

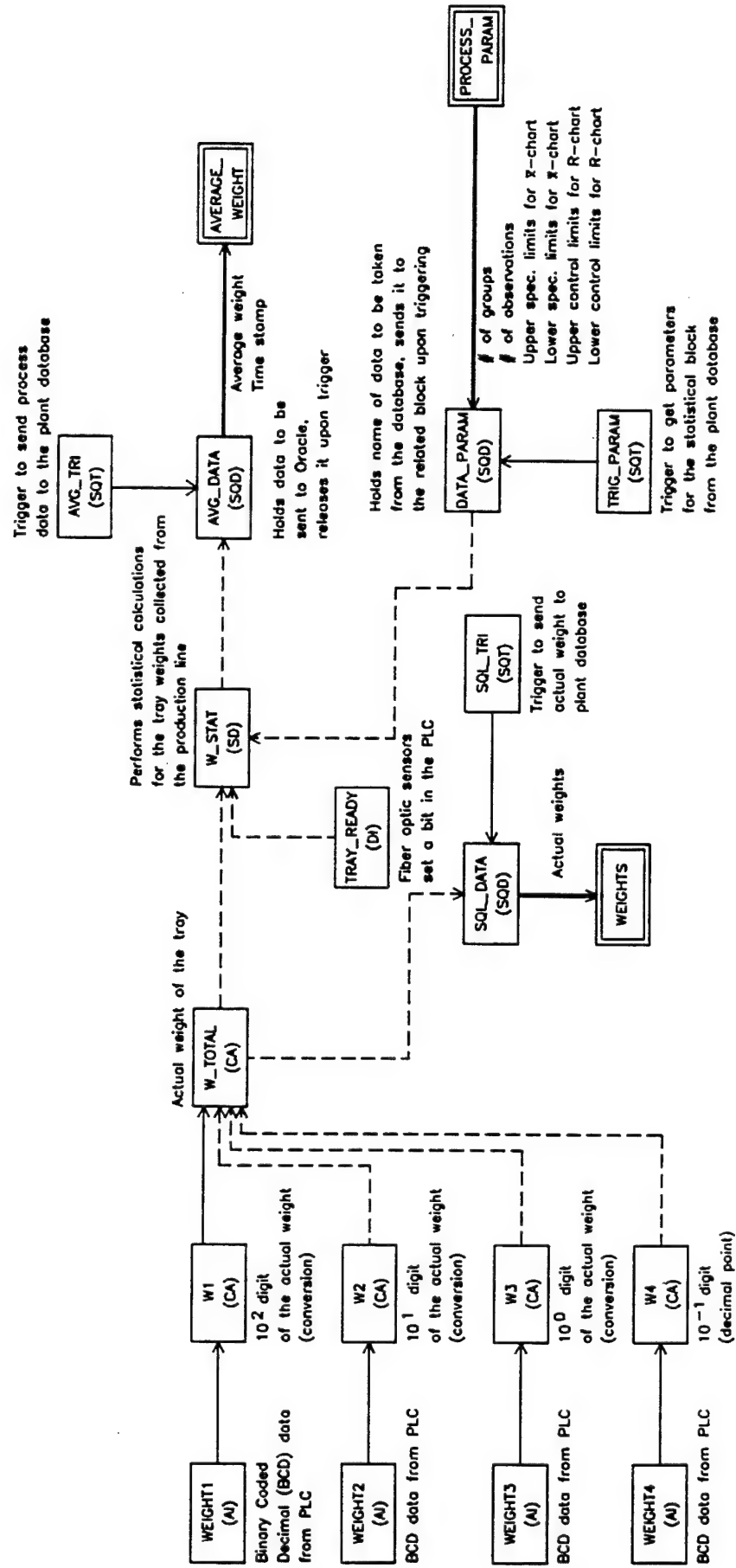


FIGURE 4.3: PROCESSING AND FLOW OF TRAY WEIGHTS DATA

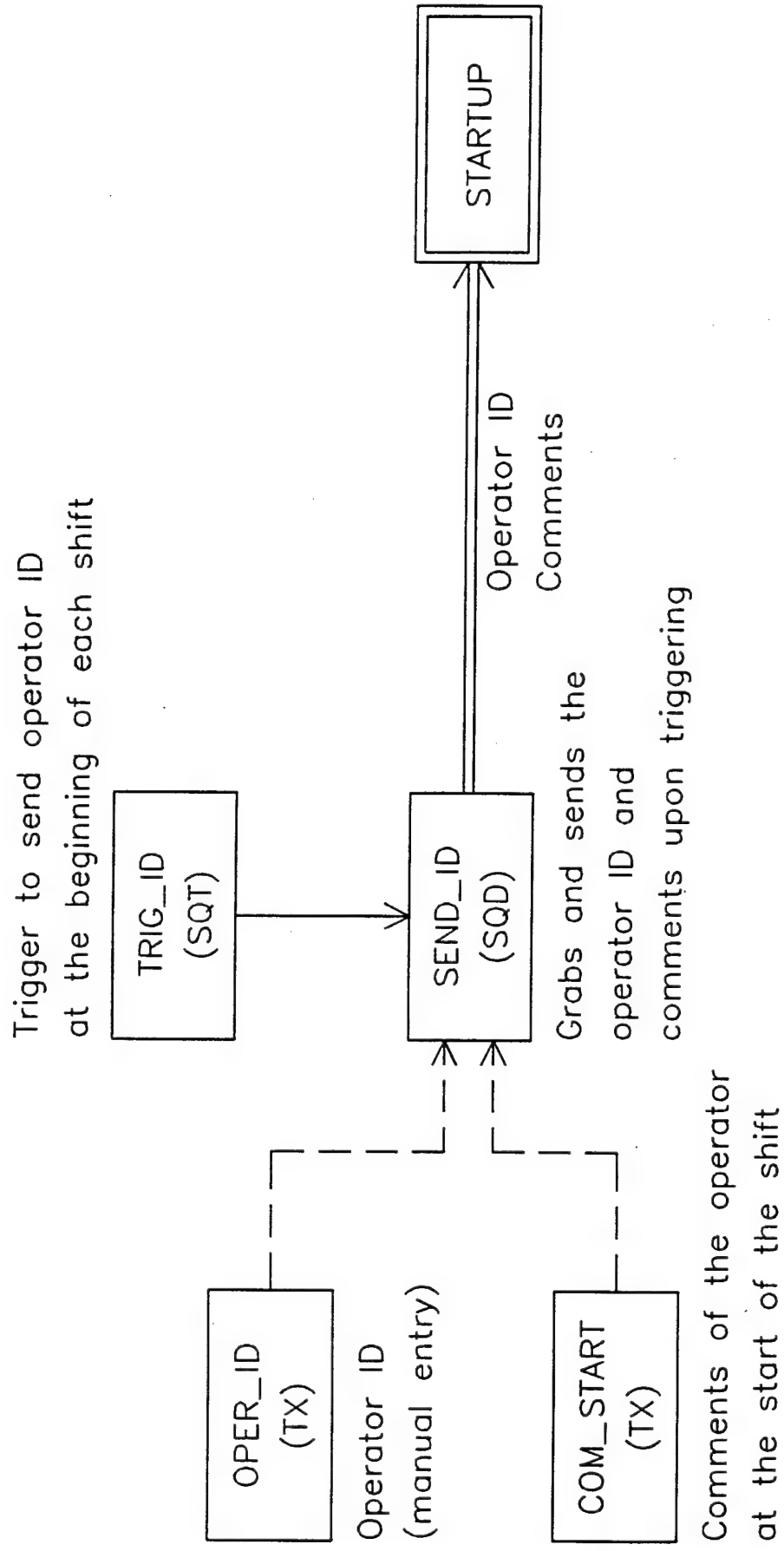


FIGURE 4.4: FLOW OF OPERATOR ID AND COMMENTS

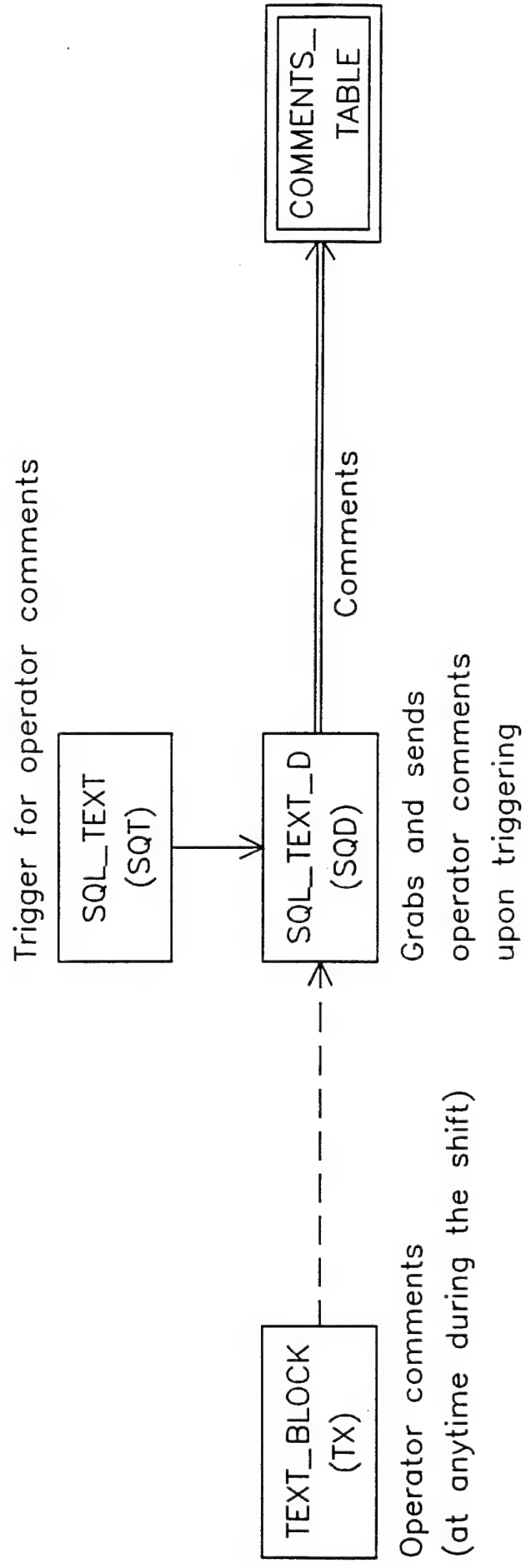


FIGURE 4.5: FLOW OF OPERATOR COMMENTS

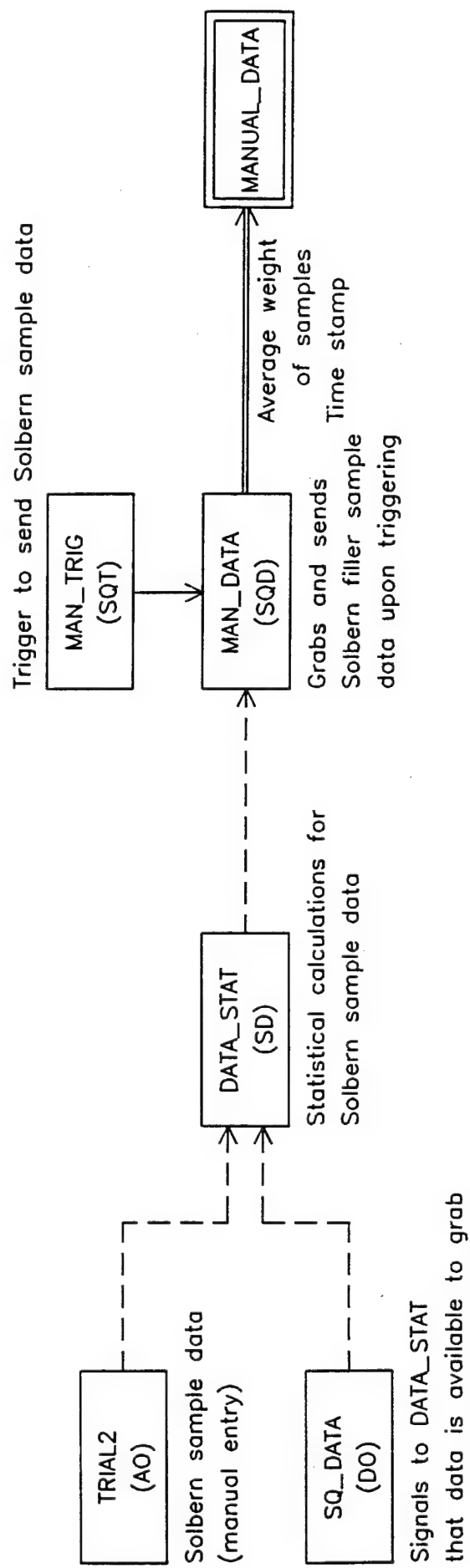


FIGURE 4.6: FLOW OF DATA COLLECTED FROM SOLBERN FILLER

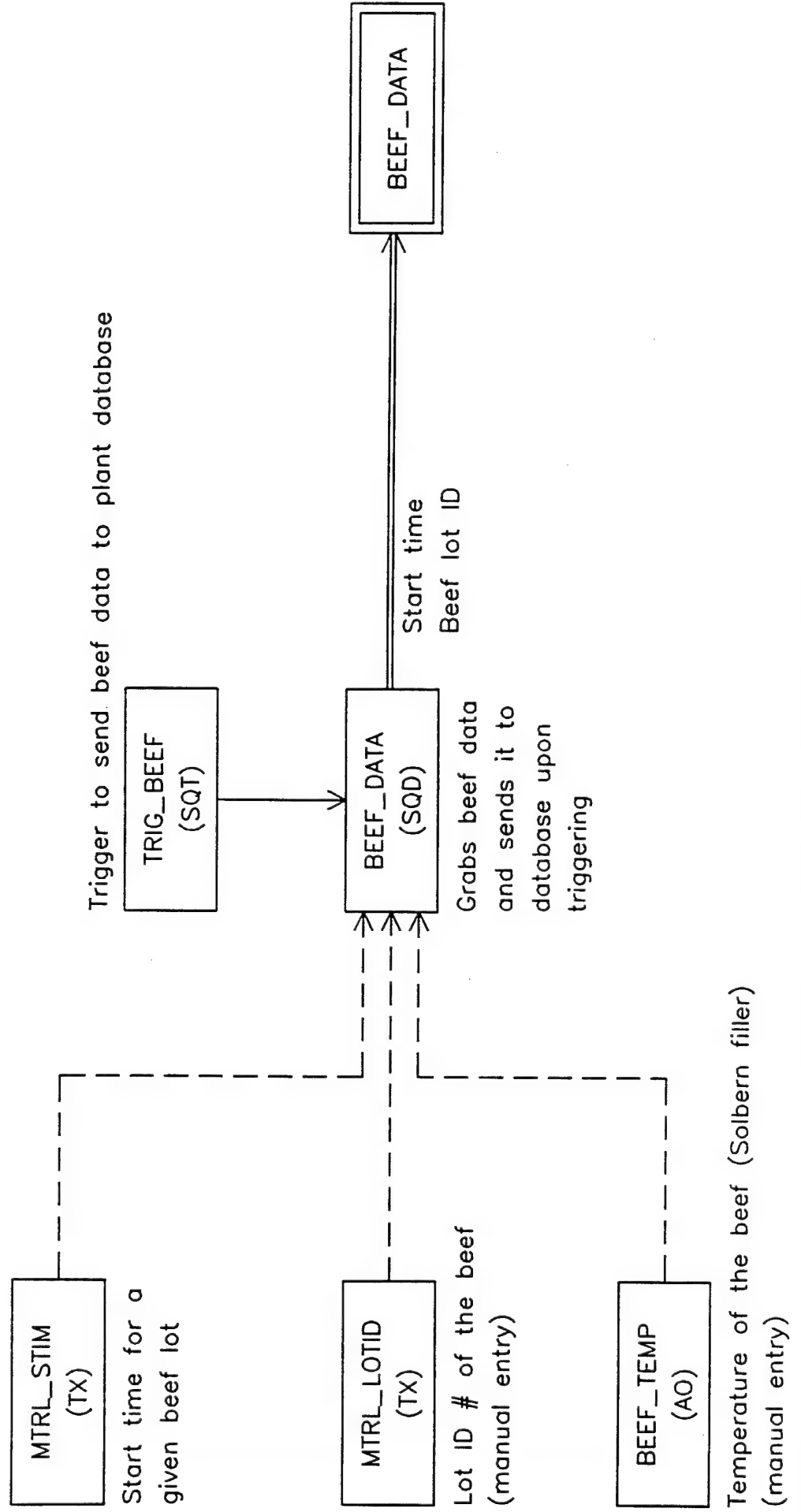


FIGURE 4.7: MATERIAL TRACKING (BEEF)

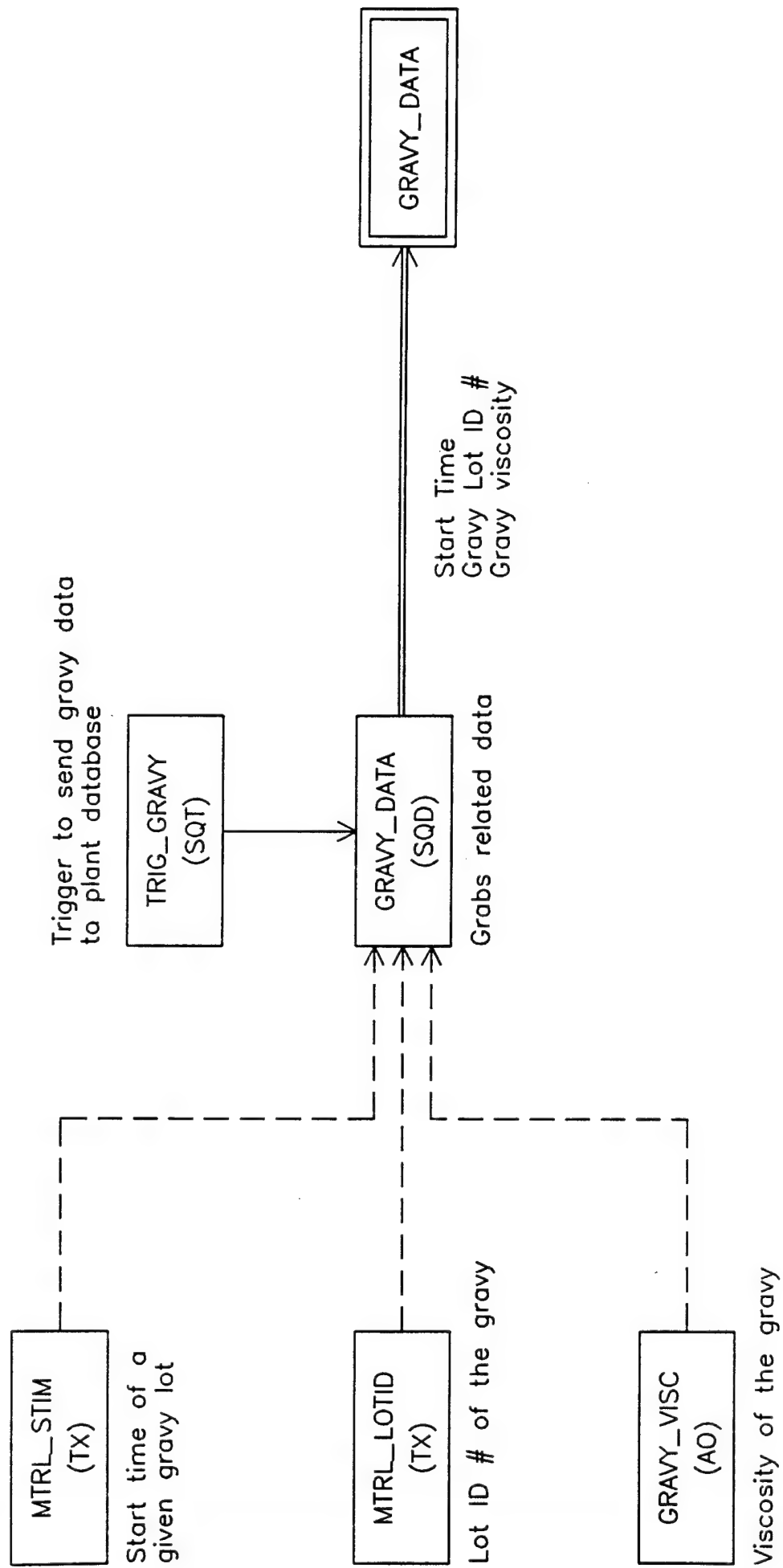


FIGURE 4.8: MATERIAL TRACKING (GRAVY)

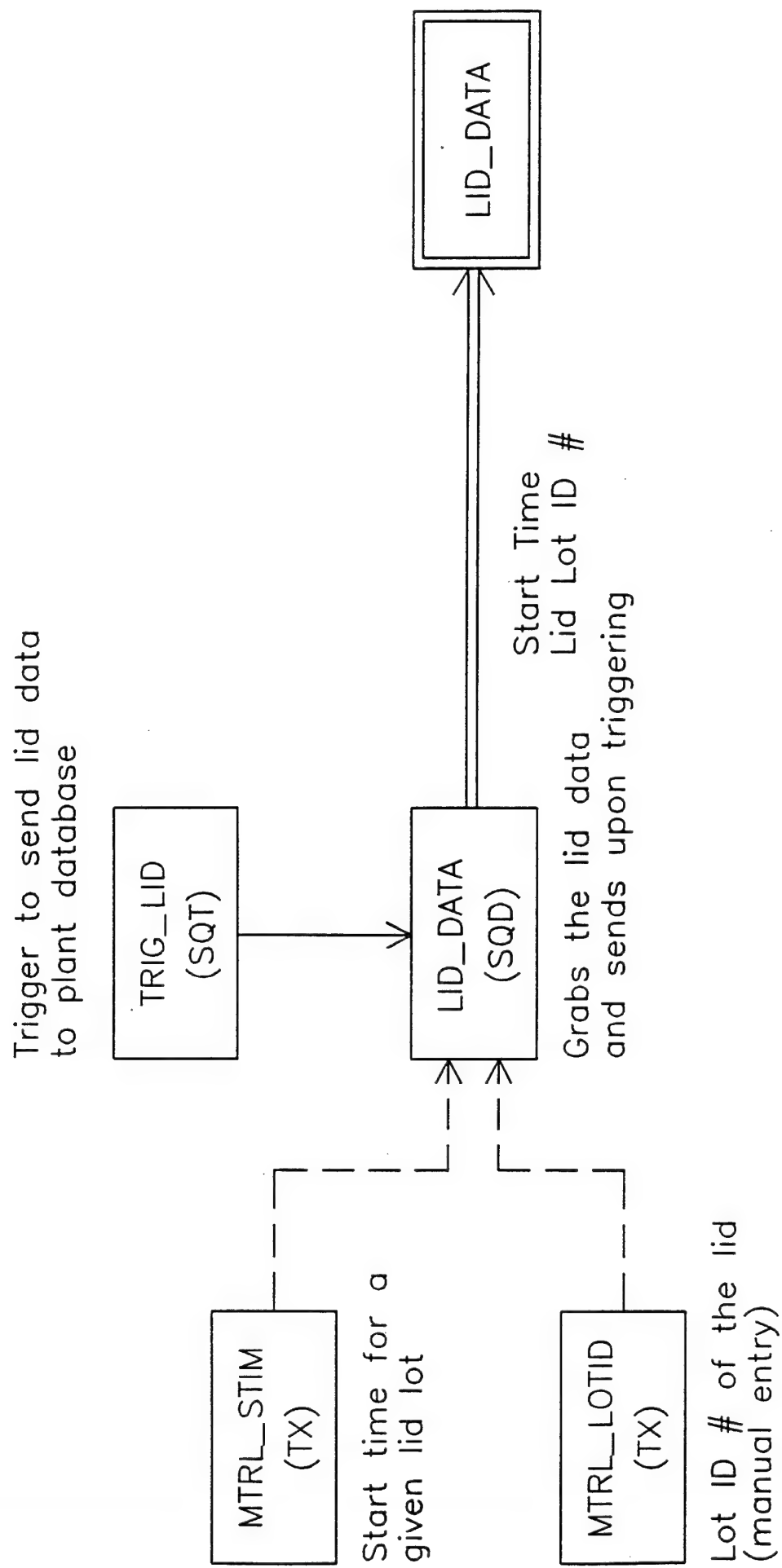


FIGURE 4.9: MATERIAL TRACKING (LID)

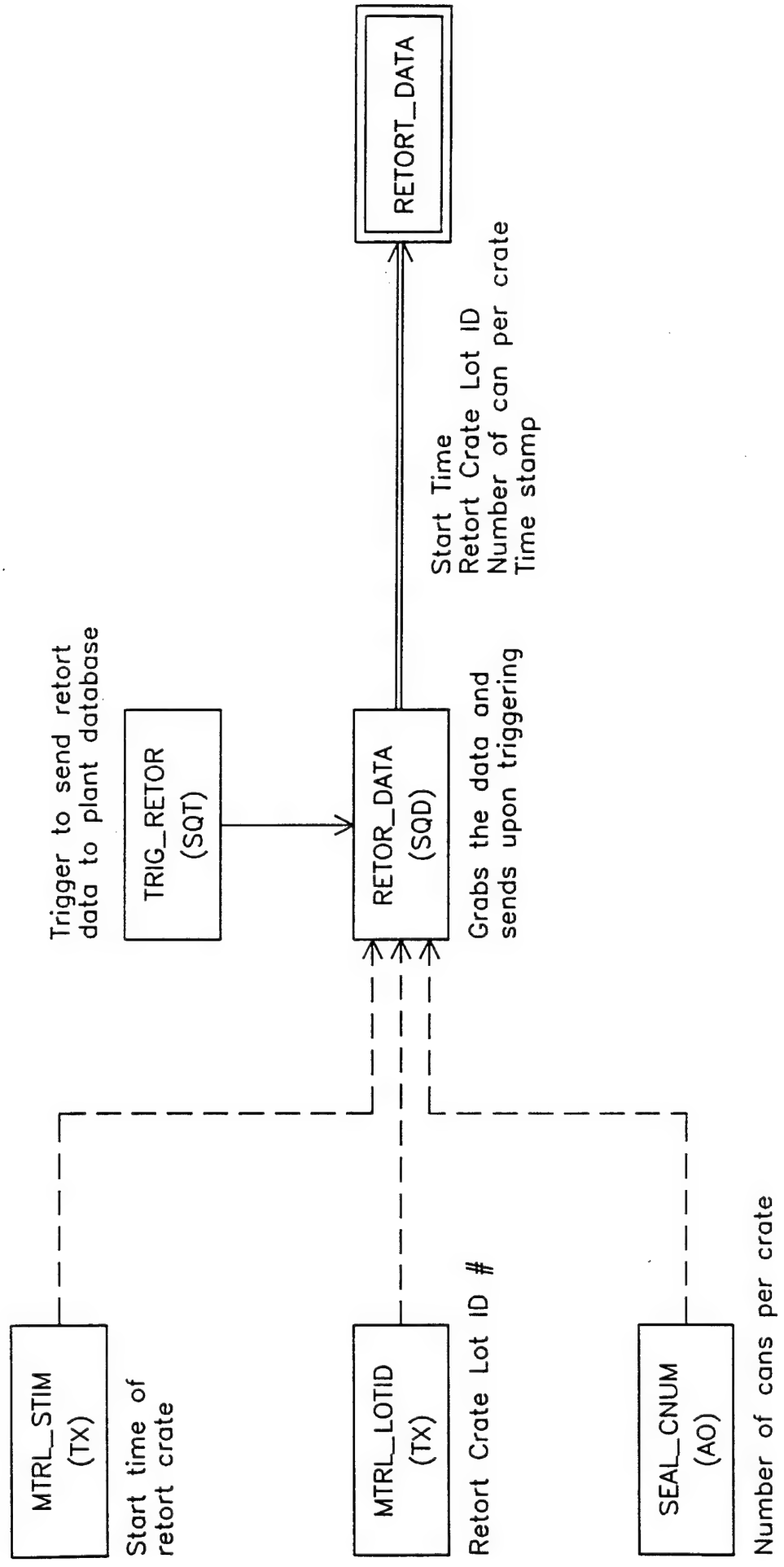


FIGURE 4.10: MATERIAL TRACKING (RETORT CRATE)

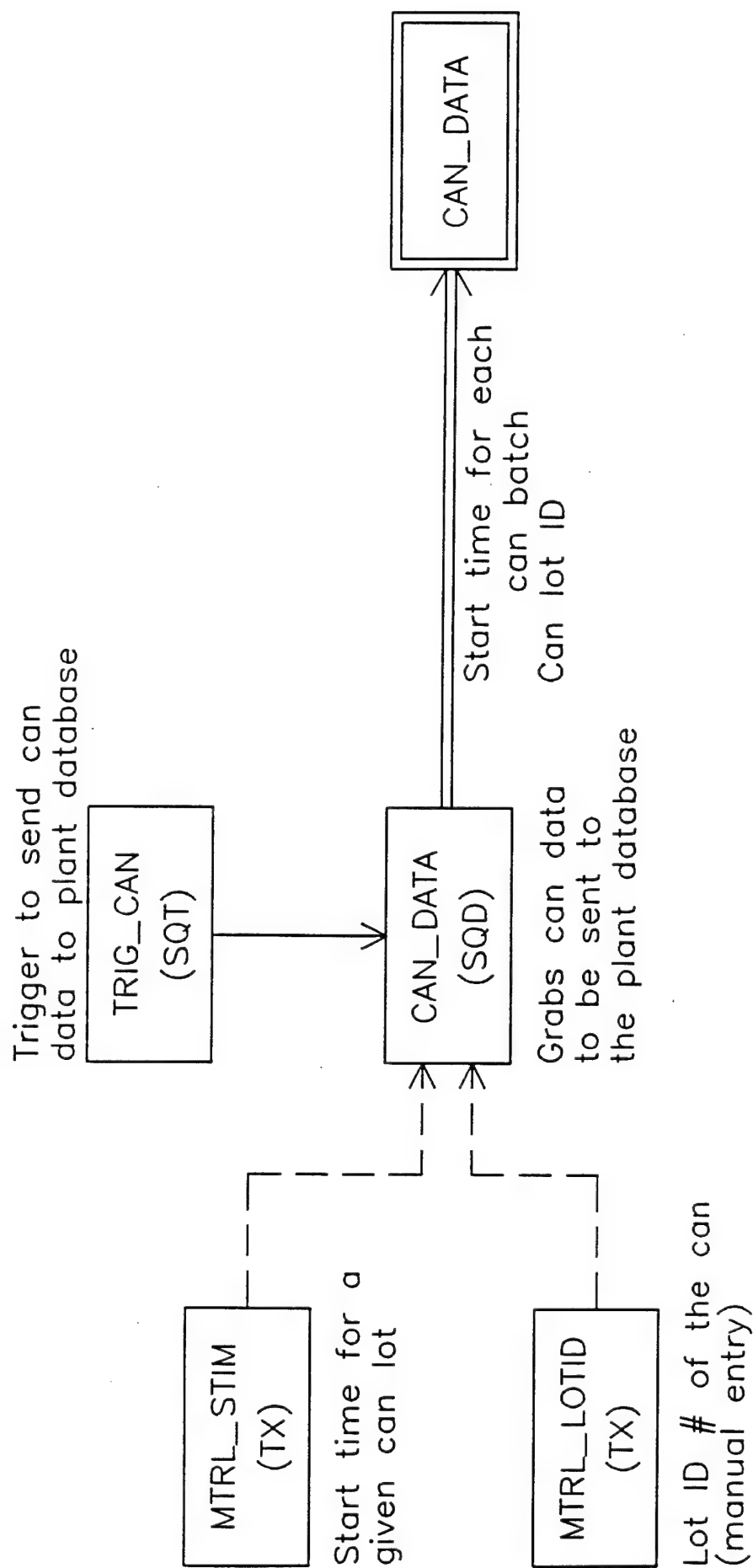


FIGURE 4.11: MATERIAL TRACKING (CAN)

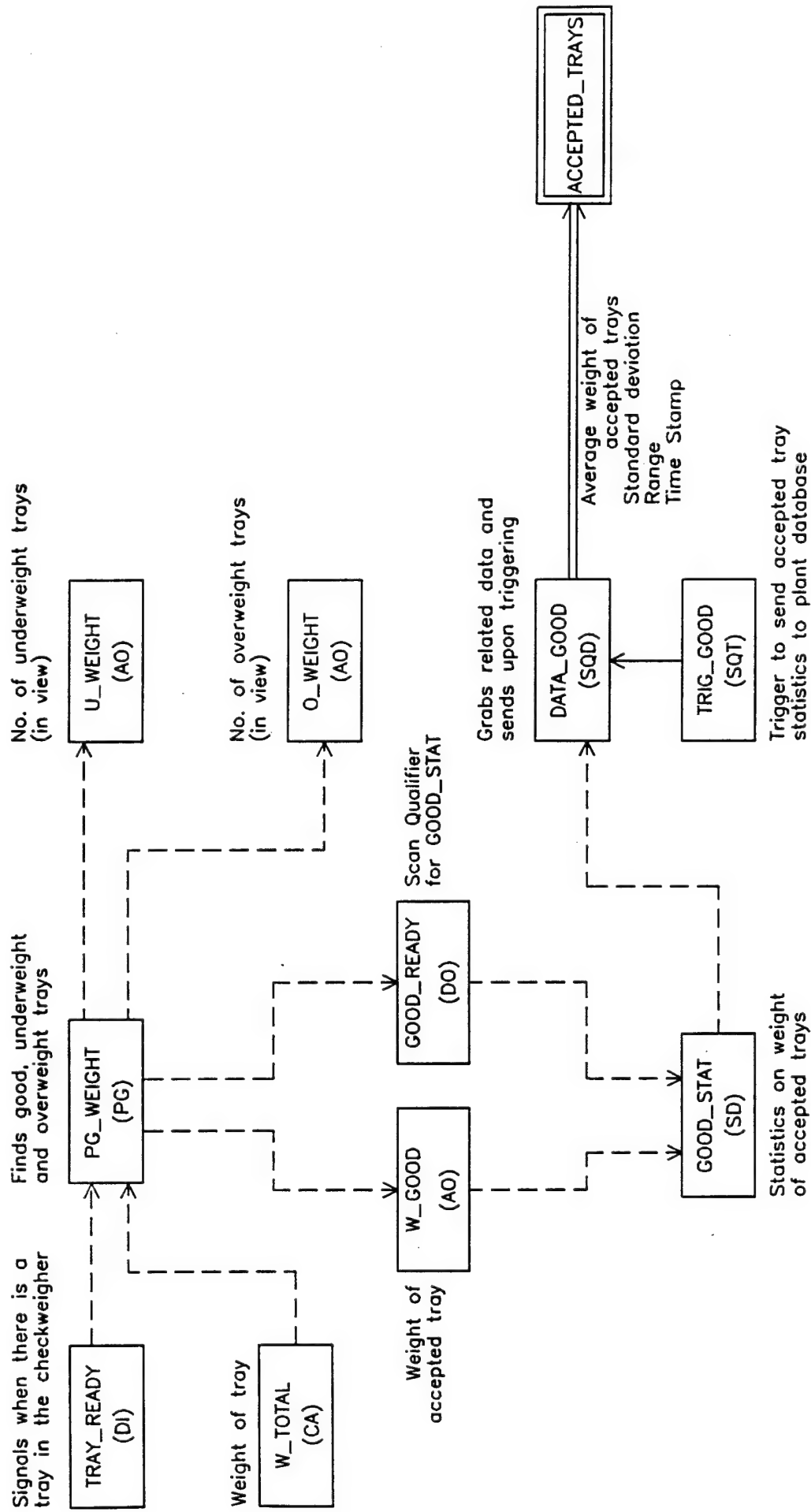


FIGURE 4.12: PROGRAM TO DIFFERENTIATE BETWEEN ACCEPTED, OVERWEIGHT AND UNDERWEIGHT TRAYS

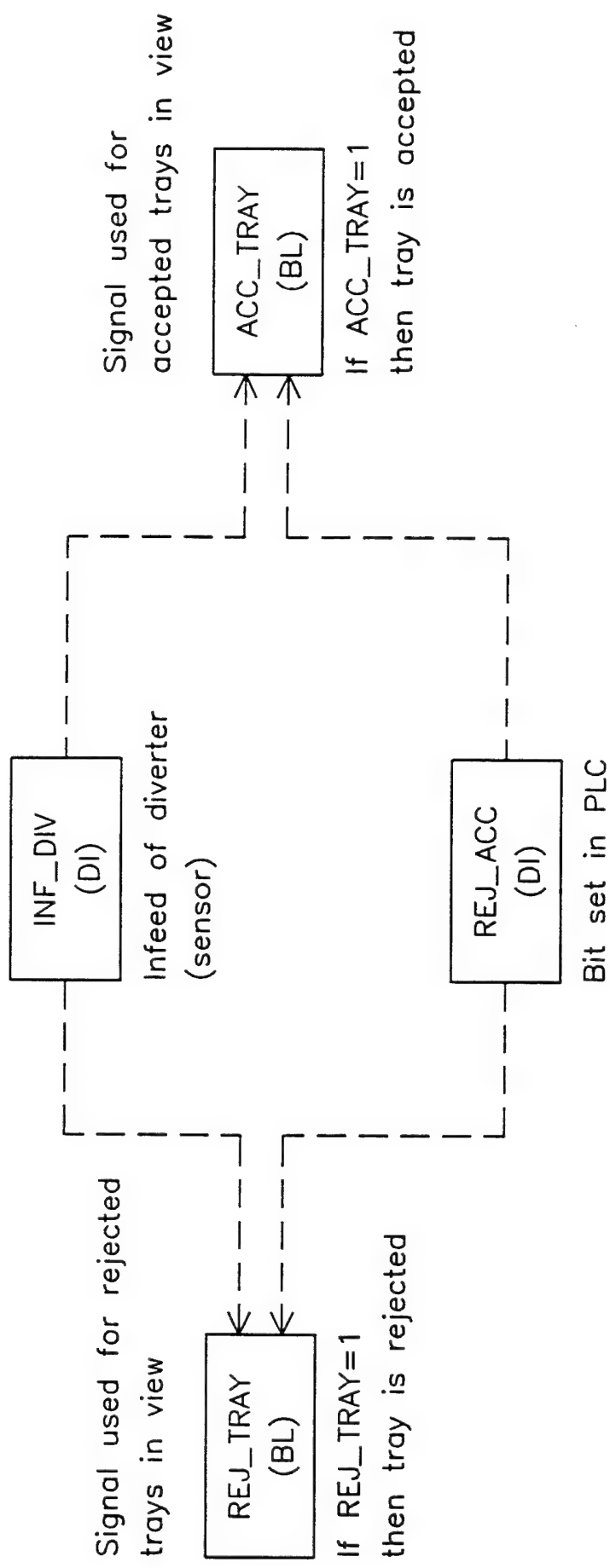
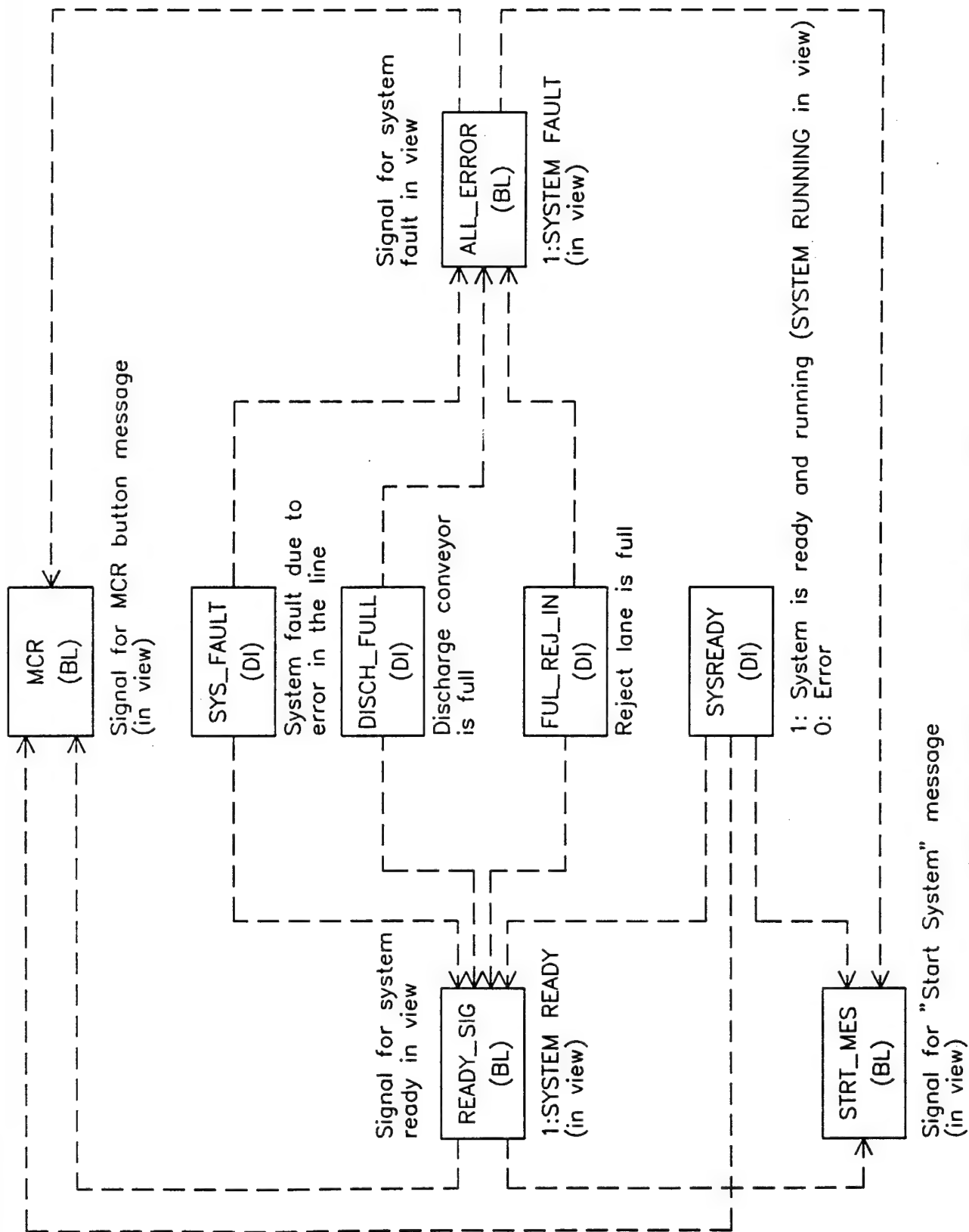


FIGURE 4.13: DISPLAYS ACCEPTED AND REJECTED TRAYS IN VIEW



(All the digital inputs are bits in the PLC)

FIGURE 4.14: SYSTEM STATUS DISPLAY

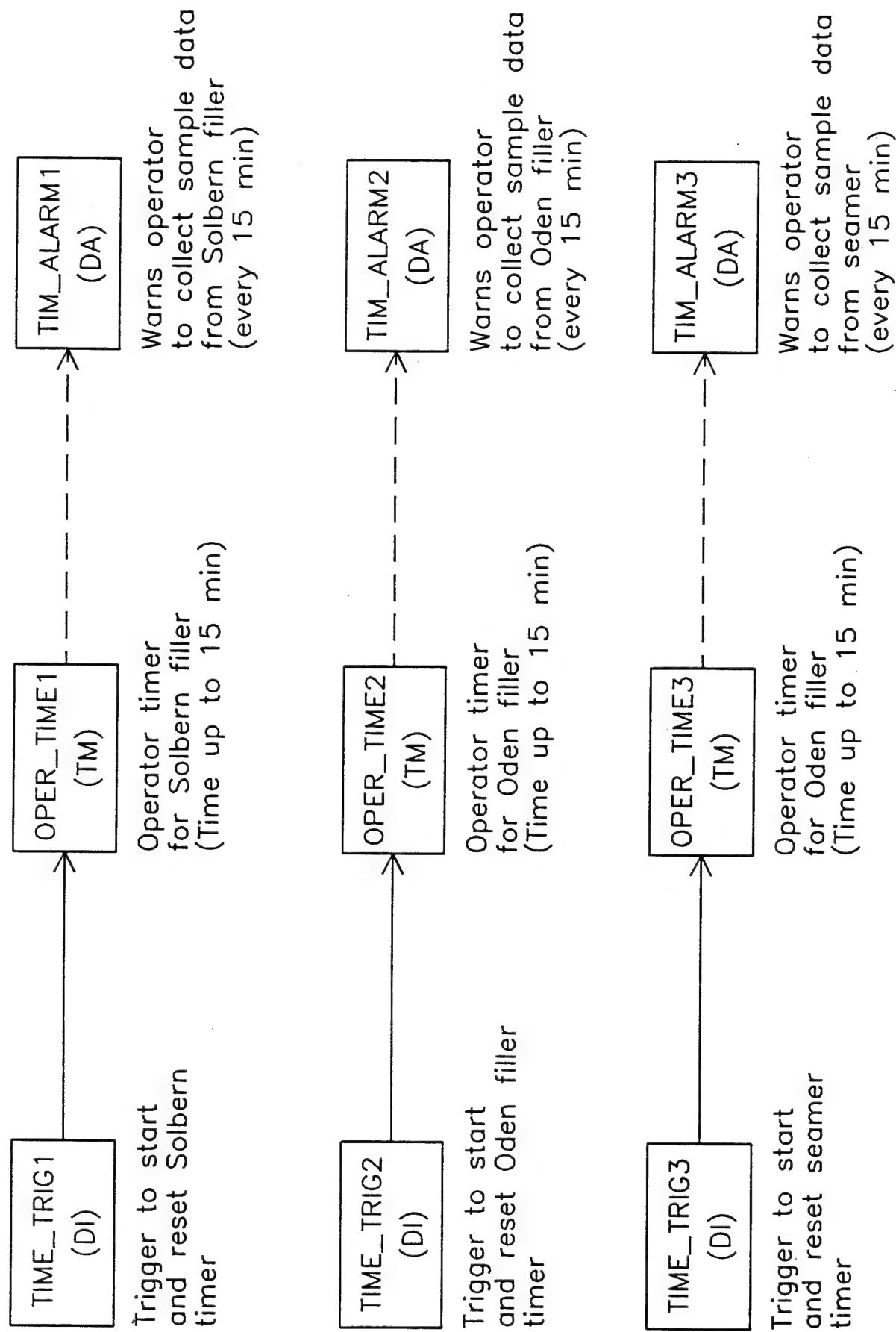


FIGURE 4.15: OPERATOR TIMERS FOR PRODUCT SAMPLING

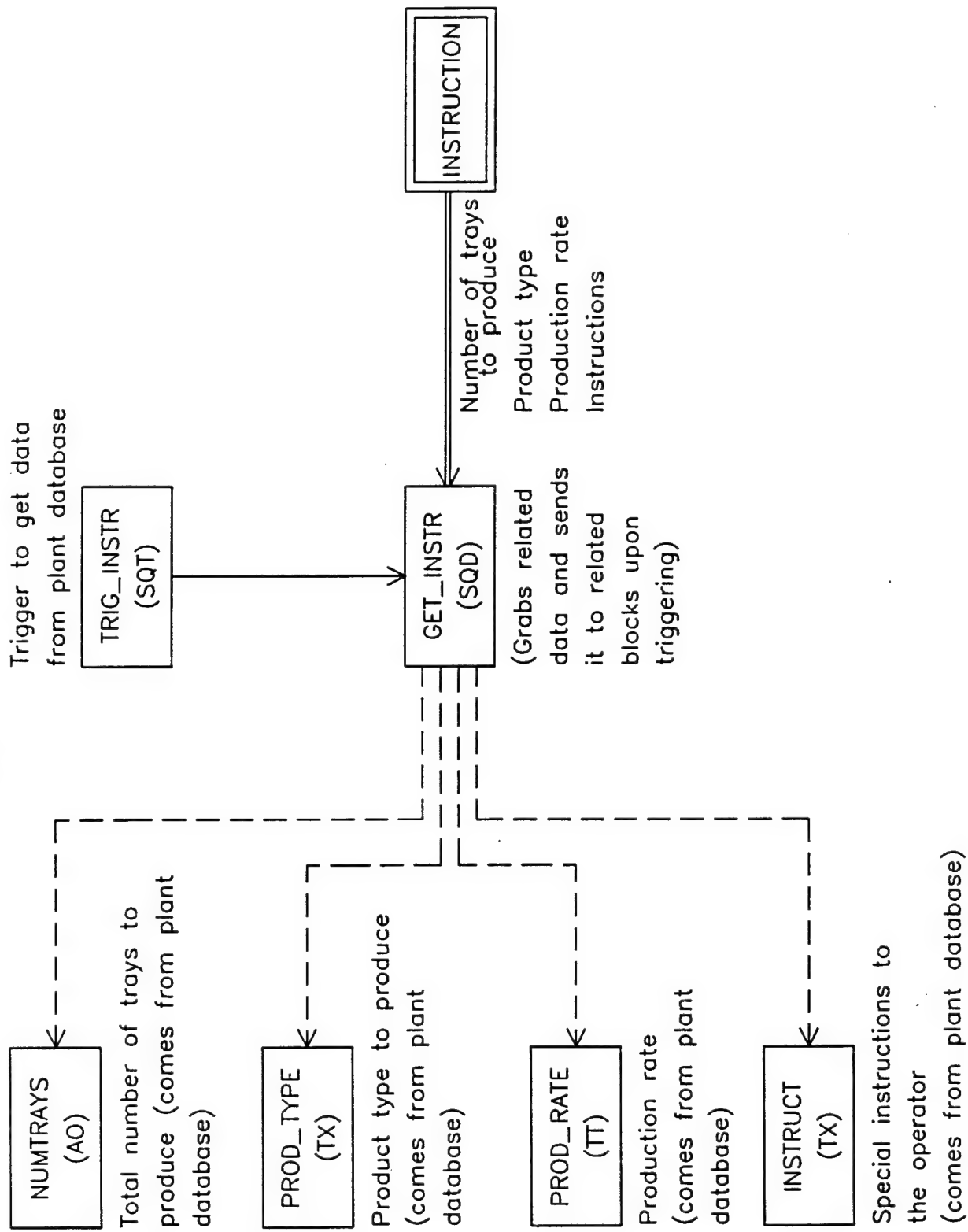


FIGURE 4.16: SCHEDULE FROM PLANT DATABASE

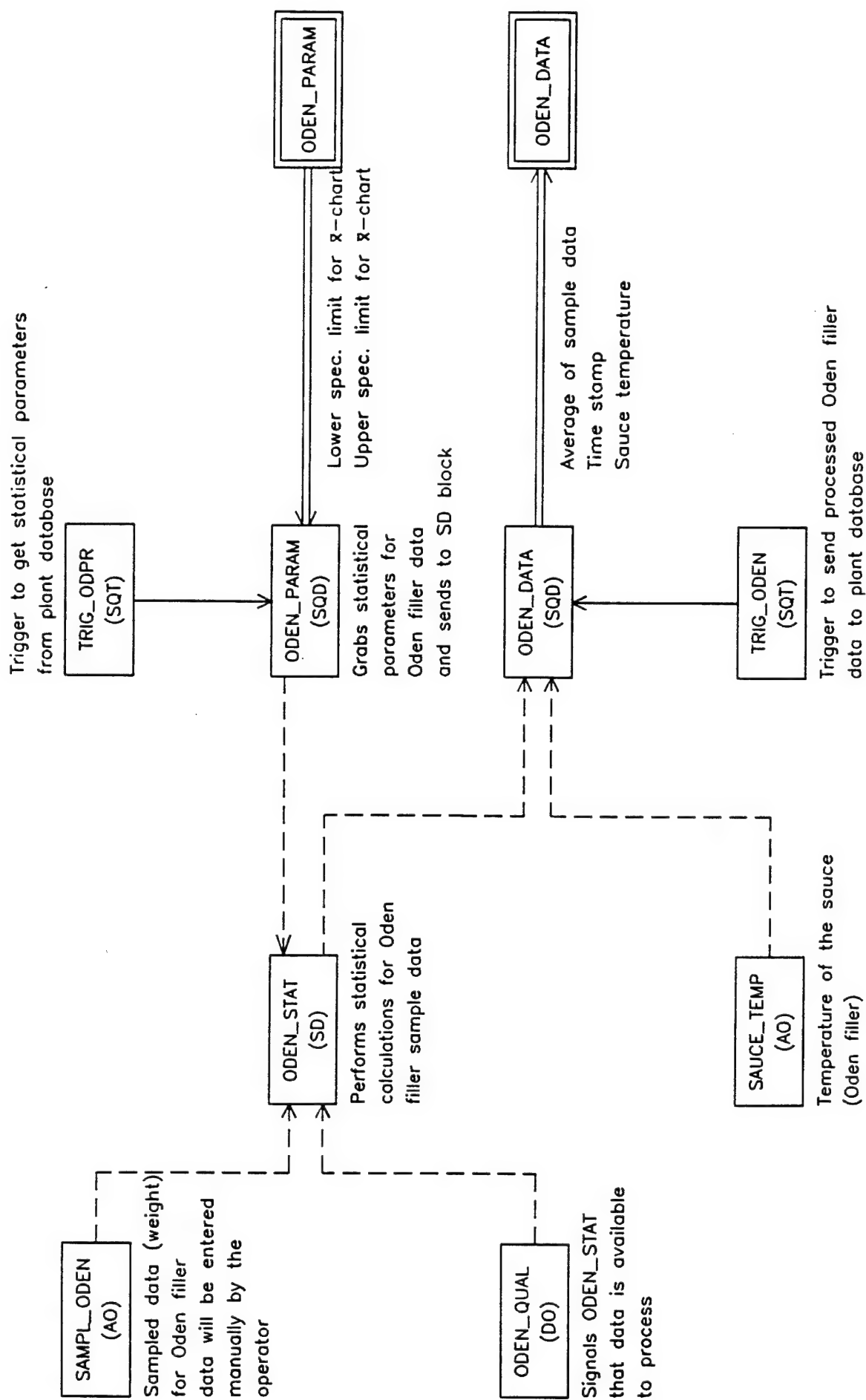
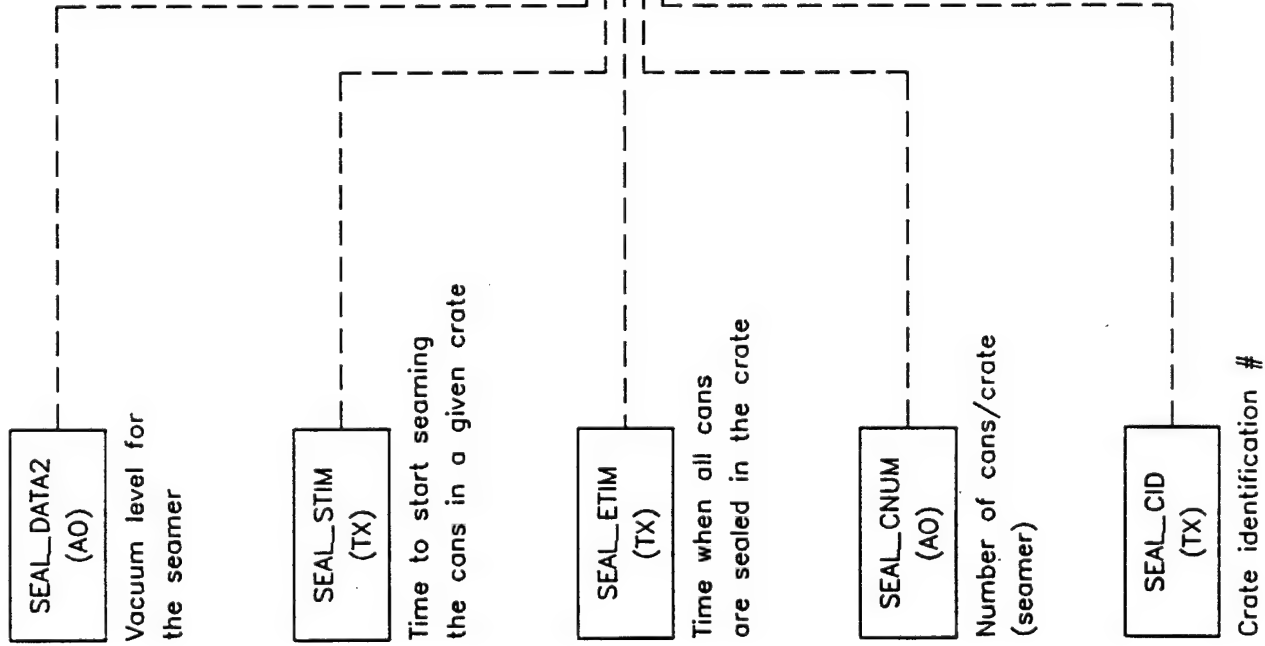
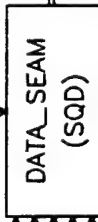
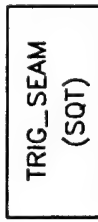


FIGURE 4.17: FLOW OF DATA COLLECTED FROM ODEN FILLER

(All the below data will be entered manually by the operator)



Trigger to send seamer data to plant database



Grabs seamer data to be sent to the plant database
Sends them upon triggering



Vacuum level
Start time for each crate
Number of cans/crate
Crate ID

FIGURE 4.18: FLOW OF DATA COLLECTED FROM SEAMER

**COMBAT RATION
ADVANCED MANUFACTURING
TECHNOLOGY DEMONSTRATION
(CRAMTD)**

**MRE Pouch Line: Automatic Data Collection
and Display Development**

Technical Working Paper (TWP) 109

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1. Introduction

In this paper we describe the implementation of FIX DMACS to the MRE Pouch Line as a requirement of STP #16. The plan is to acquire data from the production line using the Allen Bradley Series 2 Programmable Logic Controller (PLC) and then send it to shop floor PC. Some retrieved data will be manipulated in the PC through certain applications, such as the data to be used for quality control purposes. Finally, processed data will be uploaded to a central database for record keeping and data analysis. FIX DMACS, an industrial automation software, is used to achieve this end. A brief overview of FIX DMACS is already presented in earlier technical reports. The readers are referred to TWP #88 and TWP #103 for details on FIX DMACS. The outline of the report is summarized as follows: In section 2, we discuss how to configure the system to establish communication with the hardware components. Section 3 gives an overview of the FIX DMACS database built for MRE pouch line. Throughout the project operator displays are designed to view the line data. Section 4 describes the display development. In section 5 we present the alarming and messaging functions. Finally, section 6 concludes the report.

2. System Configuration

In order to retrieve raw data from the process and write back to PLC there are 3 preliminary steps that must be done before setting up the database for the MRE Pouch line:

Step 1: *I/O Drivers must be configured.*

Since we have already configured the I/O drivers for Traypack line, no further configuration is necessary for the existing three I/O drivers: Allen Bradley KT card (ABK), Simulation I/O Driver (SIM) and Dynamic Data Exchange (DDE). Here, we skip this step. Section 3 of TWP #103 describes the I/O driver configuration.

Step 2: *Describe the hardware devices that will be accessed through the AB Data Highway Plus.*

For the Tray Pack line the hardware option was PLC5/12 and the *Primary Station Address* was set to **21**. For the MRE line the hardware option is PLC2/17 and the *Primary Station Address* is set to **40**.

Step 3: *Create the poll records:*

To create poll records, we need to specify a starting address and the length of the data field. The starting address tells the I/O driver where the range of data in the PLC begins and the length specifies how many data points to fetch. The designer should note that the poll record definition format for PLC5 of the Traypack line is different than that of PLC2/17 of the MRE Pouch line. Refer to the *I/O Driver Manual* to check for poll record formats of different hardware options. Table 2.1 below summarizes the I/O addresses that are defined as poll records for the MRE Pouch line.

Starting address:Length
70:2
110:3
376:2
434:3
440:13
570:1
625:1

Table 2.1: Summary of Poll Records for the MRE Line

Once I/O driver and poll records are configured, we can retrieve data from the process hardware and store in Driver Image Table (DIT) which is like a buffer between the process and the FIX DMACS database. In the next section, we will describe how to relate each poll record with a block in the database. For more details on the system configuration refer to *I/O Driver Manual* and *System Setup Manual*.

3. The Database

Through poll records we retrieve a group of data points all together. In application, however, we need to identify and utilize each individual data point (i.e. a bit or a register in PLC). Hence, *tag*

names are designer defined names given to each data point in the FIX DMACS database. Whenever a particular piece of information is needed in a FIX DMACS application, it will be called by its tag name (rather than its address in the PLC).

Since the FIX DMACS database is responsible for data processing as well as data acquisition of different types of data, there are separate types of blocks in the database. Table 3.1 shows the block types and the related abbreviations used in this document.

Block Type	Abbreviation
Analog Input Block	AI
Analog Output Block	AO
Boolean Block	BL
Calculation Block	CA
Digital Input Block	DI
Digital Output Block	DO
Fanout Block	FN
Statistical Data Block	SD
SQL Data Block	SQD
SQL Trigger Block	SQT
Program Block	PG
Timer Block	TM
Totalizer Block	TT
Text Block	TX

Table 3.1: List of Blocks used in MRE Pouch Line database design

In this section we will not discuss the details of building the database. Instead we will present a detailed profile of the database that is built for the MRE Pouch Line through figures 3.2-3.13. These figures illustrate the blocks in the MRE Line database and the flow of data between them.

Figure 3.1 is the legend for the following 12 figures. For more details about a specific database block, the reader can refer to *Intellution Database Builder Manual*.

Not all the blocks in the database are in a chain with others. The blocks in table 3.2 below is not in a chain with any other block, yet they are used in the design of operator interfaces to signal fault conditions of the MRE Line.

Table 3.2: Digital Inputs and Outputs that are not in a chain with other blocks in the database

Tag Name	Type	Description
CUT_DONE	DI	Cutting done in a cycle
DFT_SFT_FL	DI	Defective safety flag
FORM_CY_WD	DI	Forming Cycle watchdog
FORM_DONE	DI	Forming done in a cycle
FORM_TL_DW	DI	Forming tools down watchdog
FORM_TL_UP	DI	Forming tools down watchdog
HI_PRT_DTC	DI	High part detected
IDX_WD_F	DI	Index watchdog failure
INDEX_COP	DI	Index complete
L_WEB_OUT	DI	Lower web out
MOVE_SWI	DI	Index of TIROMAT in motion
MRE_DOWN	DI	MRE line shut down due to Misc. Error
ROBOT_DONE	DI	Robot done in a cycle
RTD_CARD_F	DI	RTD card fault
SEAL_CY_WD	DI	Sealing cycle watchdog
SEAL_DONE	DI	Sealing done in a cycle
SEAL_TL_DW	DI	Sealing tools down watchdog
SEAL_TL_UP	DI	Sealing tools up watchdog
TOG_SWI	DI	Dummy switch

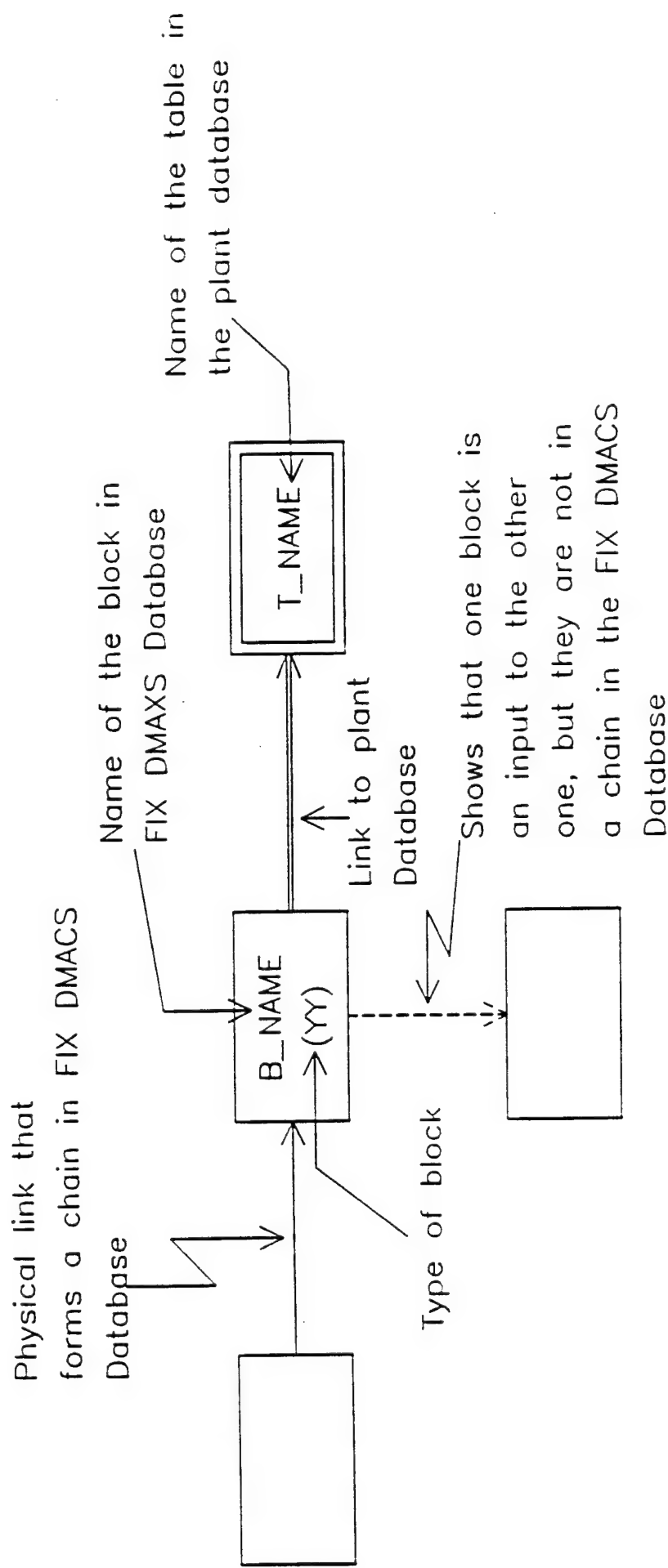


FIGURE 3.1: LEGEND FOR DATABASE BLOCK RELATIONS

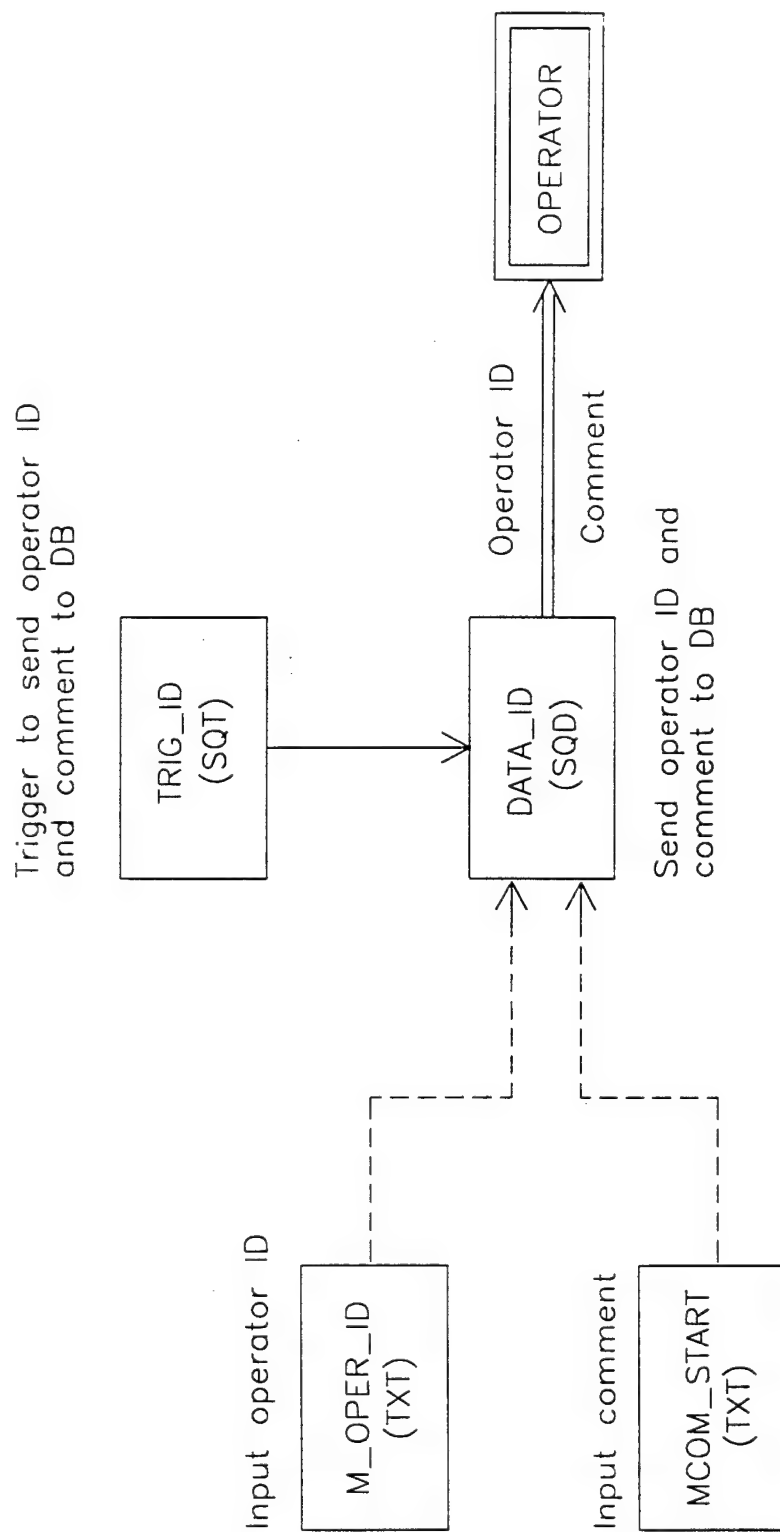


FIGURE 3.3 FLOW OF OPERATOR ID AND COMMENTS

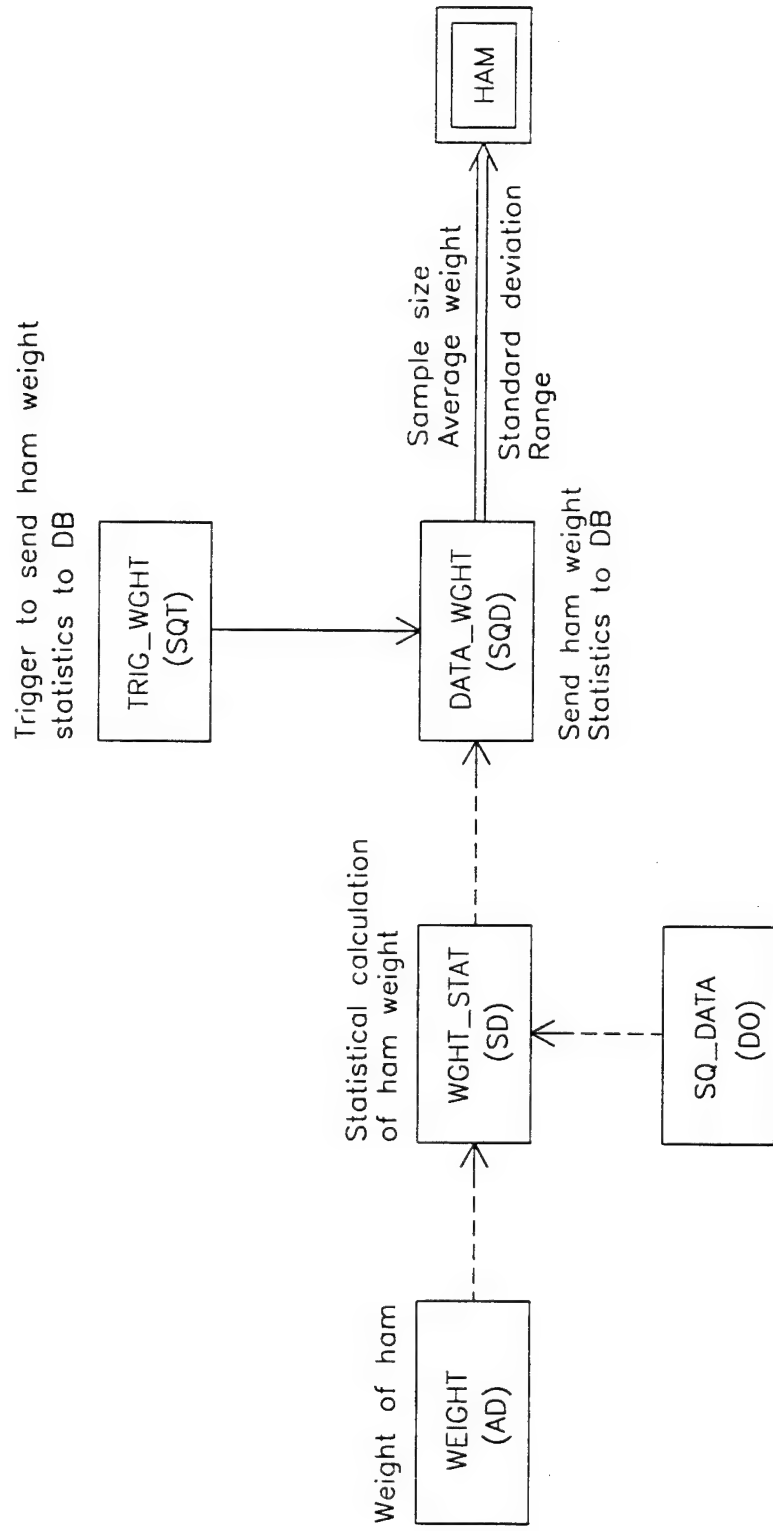


FIGURE 3.4 FLOW OF DATA COLLECTED FROM SCALE

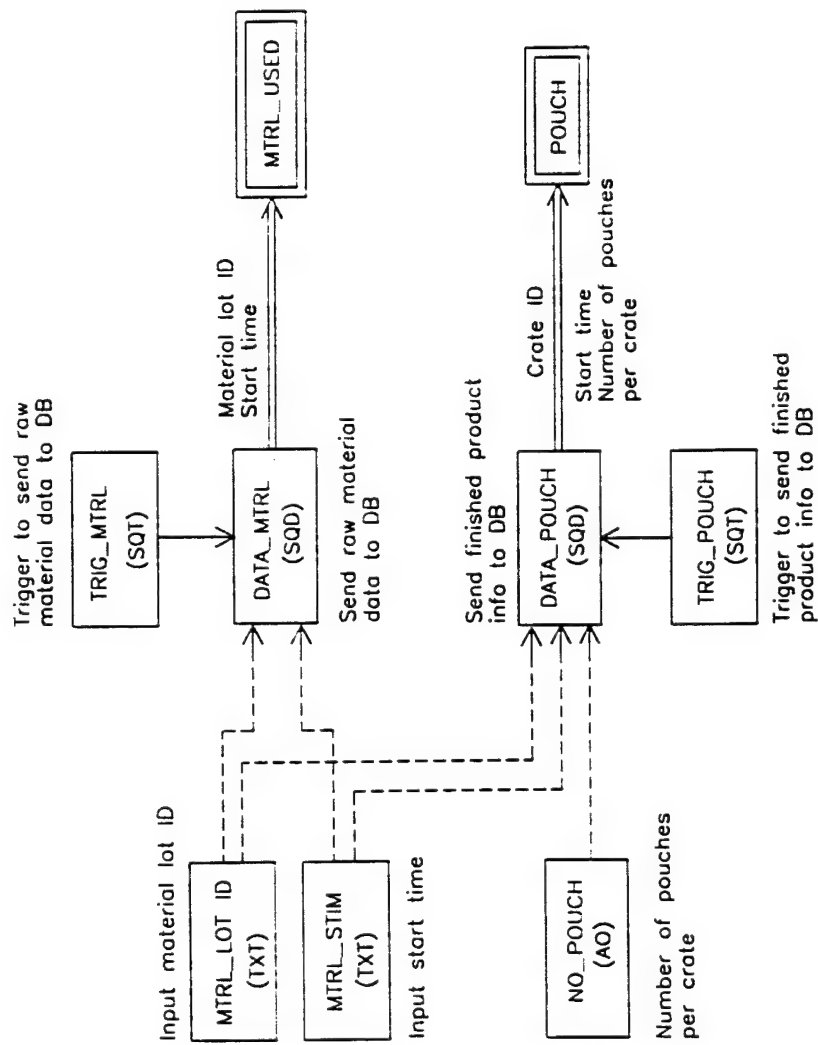
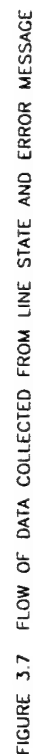


FIGURE 3.5 FLOW OF DATA IN MATERIAL TRACKING



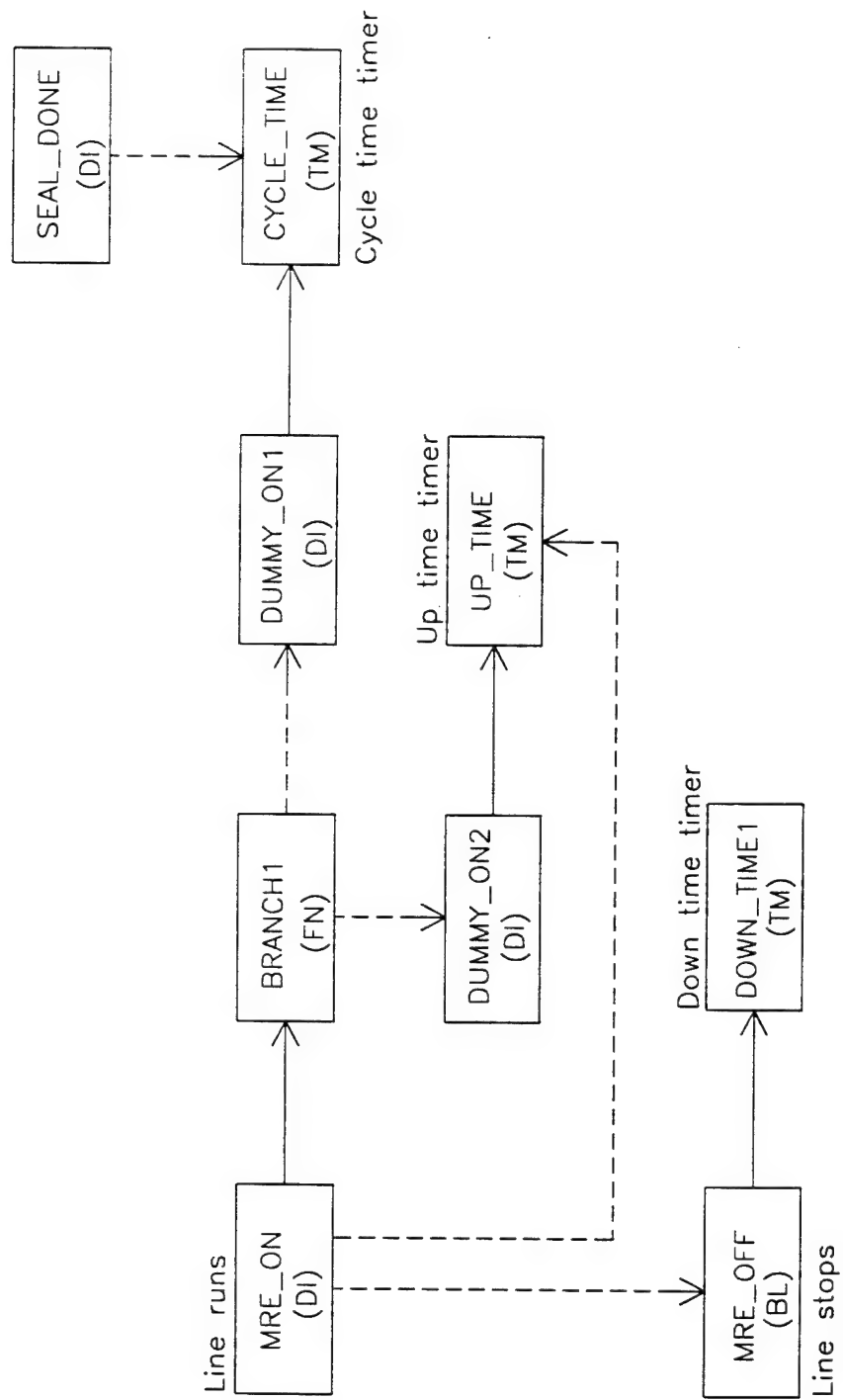


FIGURE 3.8 CALCULATE LINE PERFORMANCE DATA, INCLUDING CYCLE TIME, UP TIME AND DOWN TIME

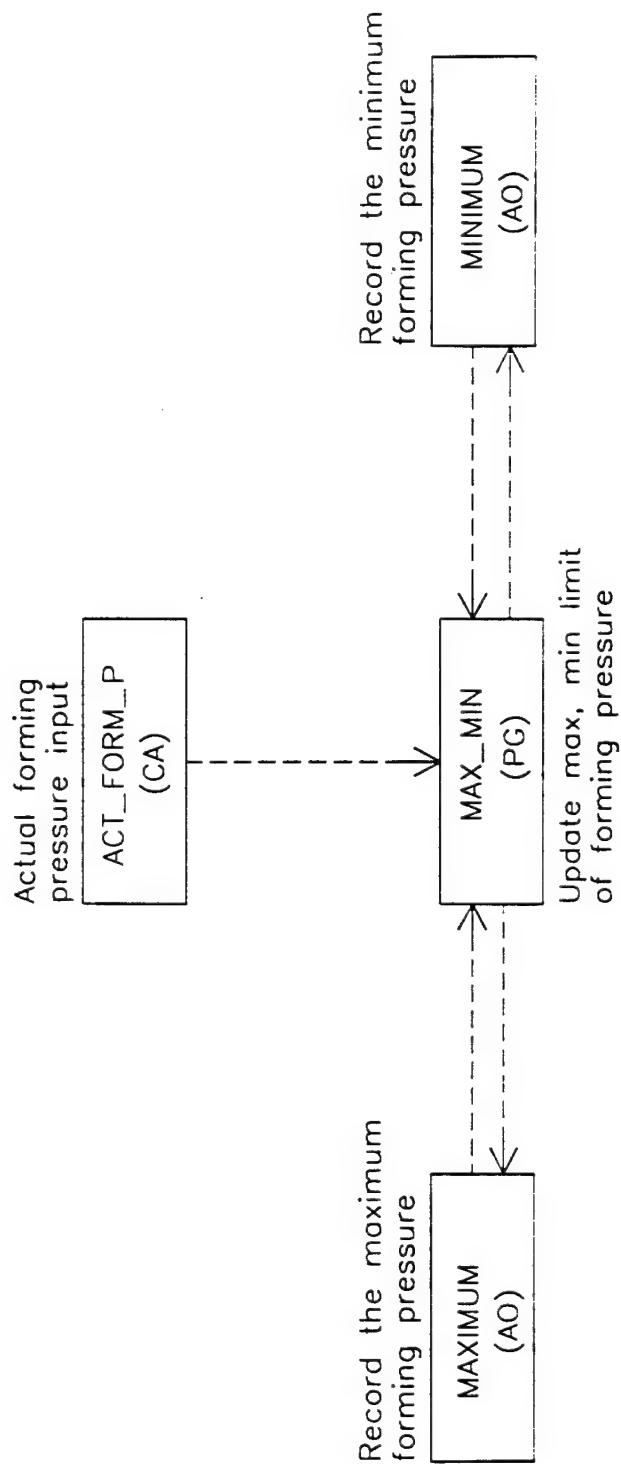


FIGURE 3.9 CALCULATE THE MAX AND MIN VALUE OF FORMING PRESSURE

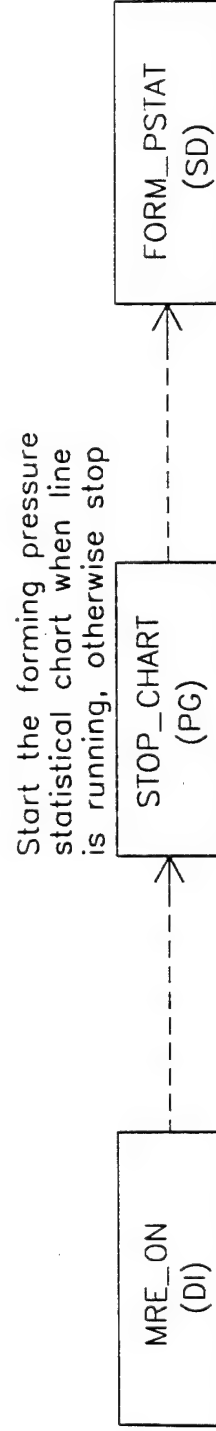


FIGURE 3.10 STOP/RUN FORMING PRESSURE STATISTICAL CHART

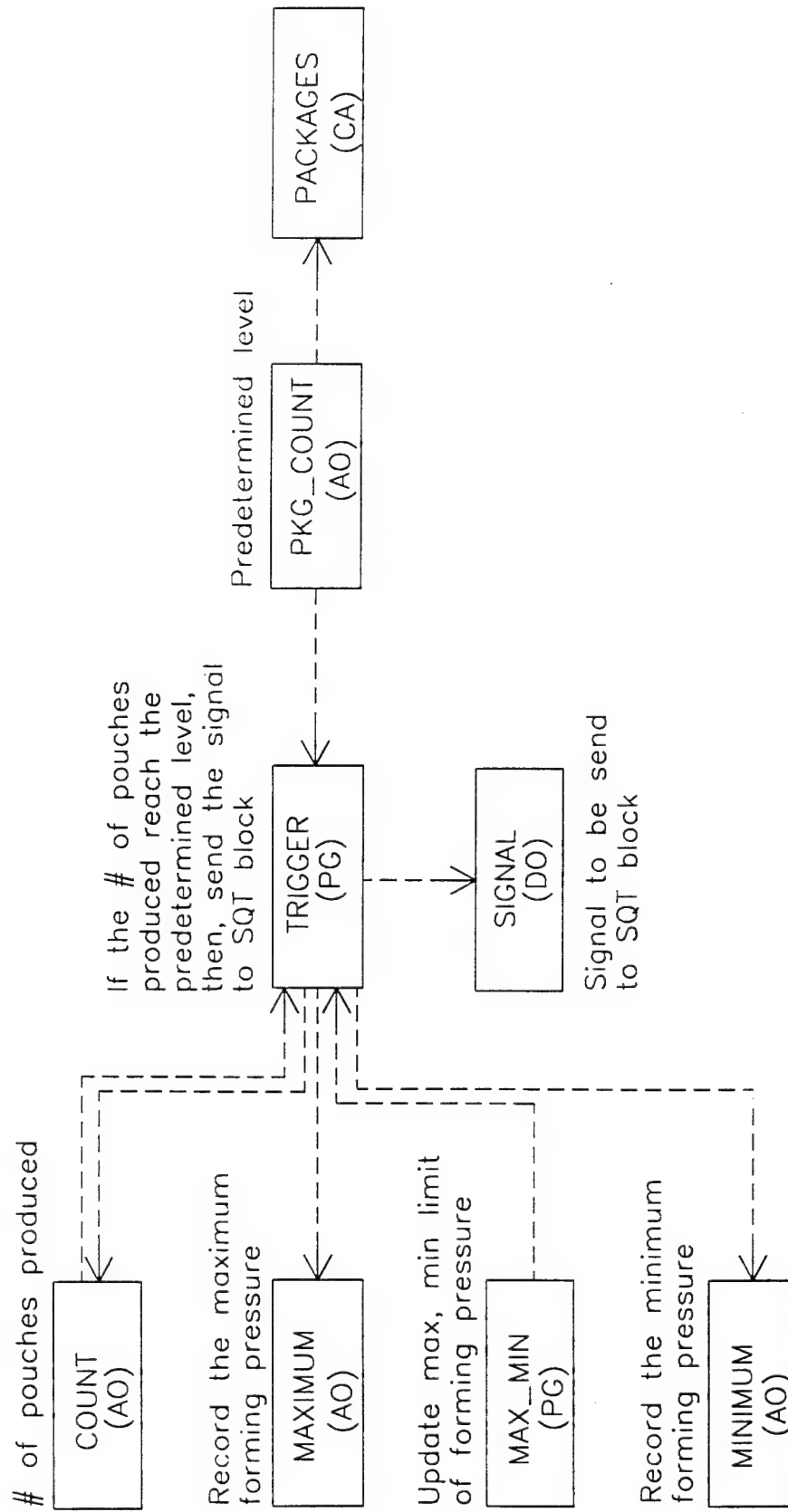


FIGURE 3.11 CALCULATE WHEN TO SEND SIGNAL TO ACTIVATE SQT BLOCKS

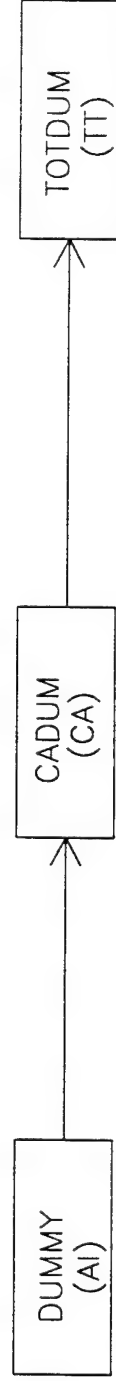


FIGURE 3.12 COUNTER FOR HAM WEIGHT SCREEN

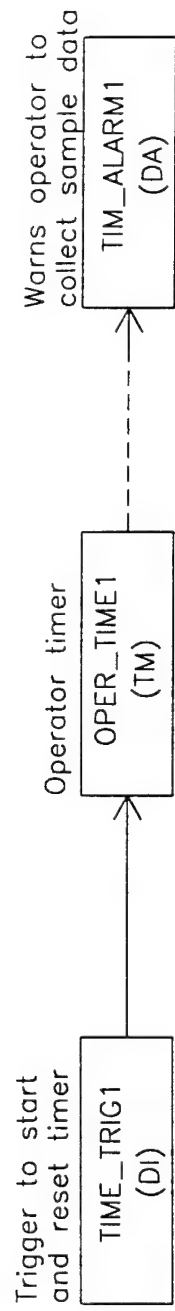


FIGURE 3.13 OPERATOR TIMERS FOR PRODUCT SAMPLING

TOG_SWI1	DI	Dummy switch
TRIG_INPUT	DI	Trigger to grab the DDE data from scale
U_WEB_OUT	DI	Upper web out
DUMMY1	DO	Dummy block for material tracking screen
DUMMY2	DO	Dummy block for material tracking screen
DUMMY3	DO	Dummy block for material tracking screen
DUMMY4	DO	Dummy block for material tracking screen
DUMMY5	DO	Dummy block for material tracking screen
FLAG	DO	Flag for "Saving..." Message in View
RESET_ERR	DO	Reset the master fault bit in PLC
SIGNAL	DO	Signal to SQTs to send data
SQ_DATA	DO	Scan qualifier for WGHT_STAT

Table 3.2: Digital Inputs and Outputs that are not in a chain with other blocks in the database

4. Display Development

In this section we will describe the operator screens that we designed to view the MRE Pouch line. *Draw* is the application used to create the pictures and *View* is the application to view the picture with real-time data. Due to the limitation of space we will not describe how each picture is created. We would rather provide a *Manual* here, which describes how to use the operator displays. For further information on creating pictures, refer to *Intellution Draw Manual*.

We designed 9 displays to view the MRE line, enter sample data manually, receive schedule and set points from the plant database. Operator screens, the access links between them, and file names as saved in *draw* program are given in figure 4.1. The figures 4.2 through 4.10 show the individual picture for each of the operator screens as seen in *View* program.

4.1. Manual for the MRE Pouch Line Operator Screens

The designed operator screens for MRE line are user friendly. The operations are mostly self explanatory. For those which may create confusions we tried to provide messages to lead the

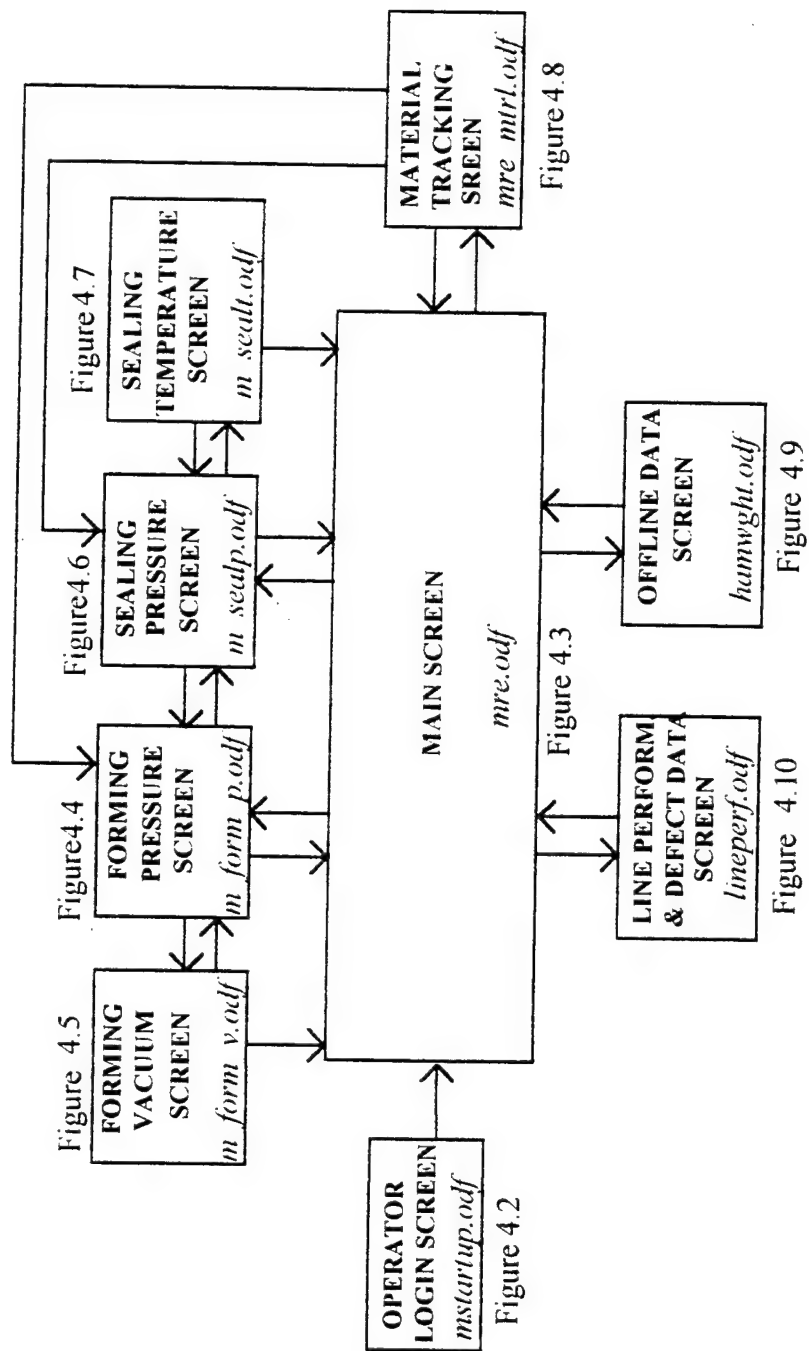


FIGURE 4.1: Screen Access Relations

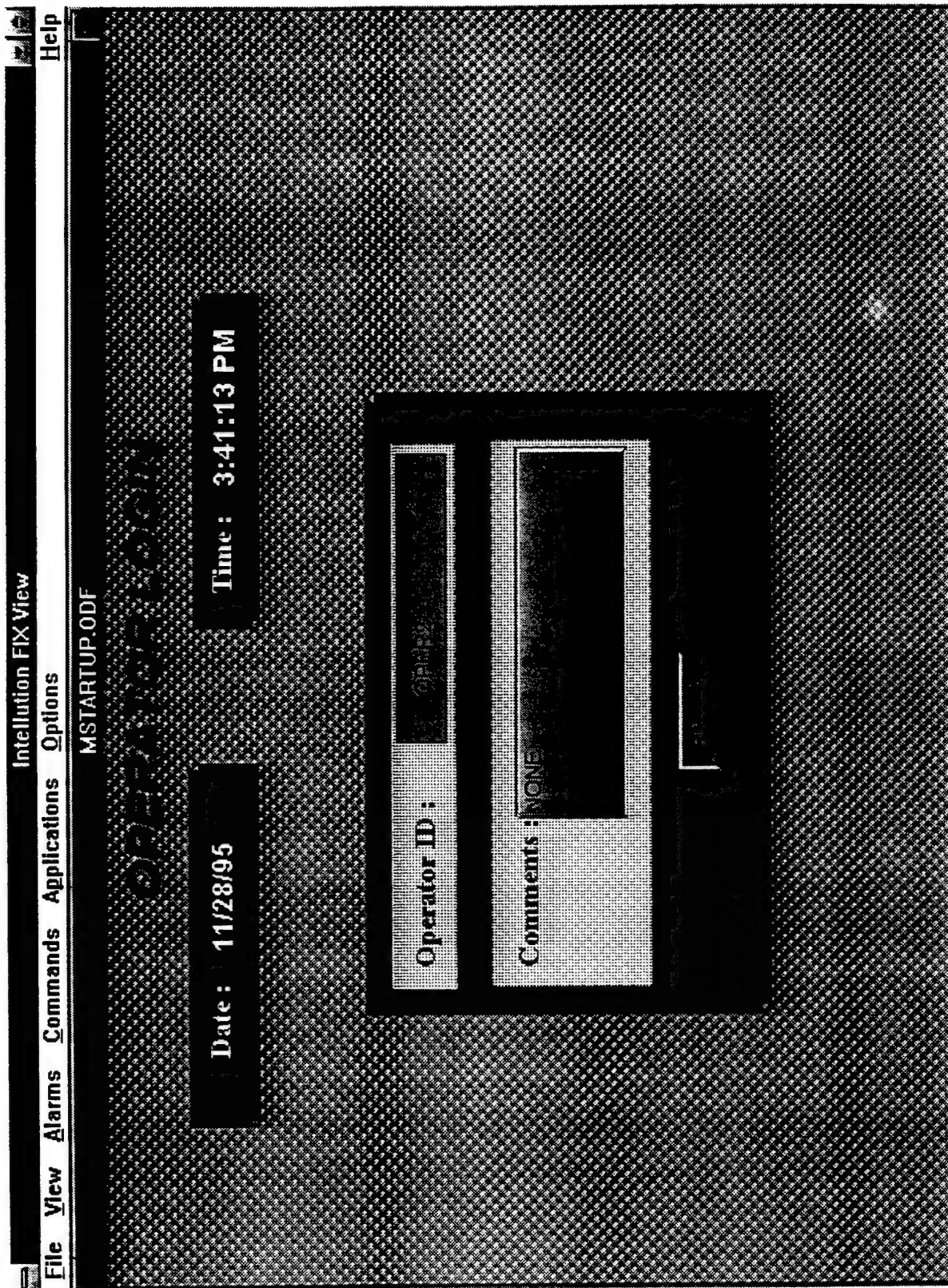


FIGURE 4.2: Operator Login Screen

operator. Next, we will go through each screen in this subsection.

4.1.1. Operator Login Screen

At the beginning of each shift, the first screen to be accessed is the *Operator Login Screen*. Refer to figure 4.2. The operator has to enter Operator ID and any comments to be made at the beginning of the shift. Upon pressing the ENTER button, a *command language* code is executed. For brief and detailed information on the command language refer to TWP #103 and *Intellution Command Language Manual*, respectively. Through the code embedded in the ENTER button in *Operator Login* screen, the information entered by the operator is saved in the plant database together with a timestamp. *MRE Line Main Screen* appears as shown in figure 4.3. All the other screens can be accessed from this screen.

4.1.2. MRE Line Main Screen

The *MRE Line Main* screen (figure 4.3) has the following features;

a) It displays a line drawing of the MRE line. A real time simulation of the process for the filling and forming stations is provided. During each cycle, 6 pouches are formed and filled at a time. The line advances to the next 6 pouches when the previous group of 6 is completed. On the *Main* screen, the operator can observe the filling and sealing process for every 6 pouches. Once the group of 6 are filled, the pouches change color from white to orange. After the sealing is complete the pouches change color from orange to green once again, which is the original color of the sealing film. The movement of the film is also simulated as it appears on the real line. At every cycle, it's possible to observe a group of 6 pouches moving forward in the line drawing.

b) It displays the type and place of the problem when a fault appears in the MRE Pouch line. FIX DMACS provides the user with the ability of alarming in case of a problem. Together with this feature, we designed the display such that each fault condition is hidden in the *MRE Line Main* screen. When an error occurs in the process, a message in red appears on the *Main* screen identifying the cause and the place of the error. This message will stay until the problem is solved and normal operating conditions are recovered. It is possible to reset the system through the control panel of the Smart System. Once the error occurs, we provide the operator with a separate dialog box (i.e. other

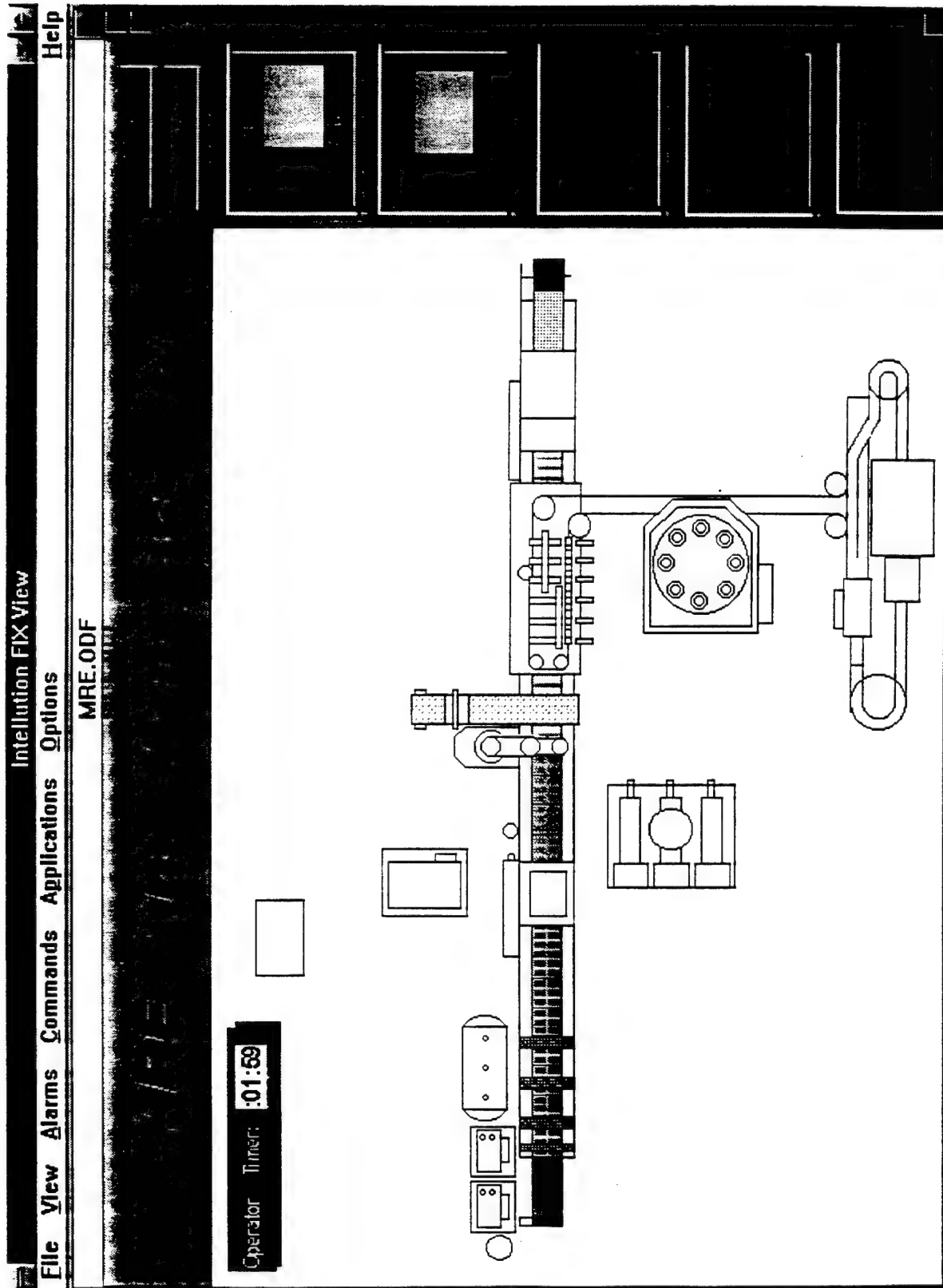


FIGURE 4.3: MRE Line Main Screen

than the error message). This feature enables the operator to reset the system through FIX DMACS as well, by simply pressing the RESET button on this dialog box. The reader notes that this application is also an example of the *control* feature provided by FIX DMACS, since we set the value of a certain bit in the PLC from FIX DMACS.

c) It displays the status of the system. There are two different states of the system shown on the upper right corner of the screen: Run (in green) and Stop (in red). System is in Running status when all the operations are performed without any fault. And Stop signal appears in case of an error as described in part b.

d) It provides the operator with the data sampling timer. Every 15 minutes, the operator or a quality control staff is required to collect and report process defect data. We will give more details on this when we discuss the *Line Performance and Defect Data* Screen. This timer (appears on the upper left corner of the screen) starts automatically at the beginning of the shift and warns the operator to enter process defect data. When the timer reaches 15 minutes, the color of timer box turns to red, a written message appears and audio signal is provided in case the horn is enabled. A written message directs the operator to the next screen where the defect data is to be entered. By clicking on the specified button, the operator switches to the *Line Performance and Defect Data* screen.

e) The main screen provides access to other screens through push buttons on the right hand side of the screen. There is a direct access to the following screens from FIX DMACS: *Forming Process Pressure Statistics*, *Sealing Process Temperature Statistics*, *MRE Line Material Tracking*, *Off-Line Data* and *Line Performance and Defect Data* screens. There is no direct access from *Main* screen to *Forming Process Vacuum Statistics* and *Sealing Process Pressure Statistics*. These screens can be accessed from *Forming Process Pressure Statistics* and *Sealing Process Temperature Statistics*, respectively. We will discuss these screens next.

4.1.3. Forming Process Pressure and Vacuum Statistics

The forming station is the post where the bottom web is given the shape of a pouch. The two parameters of interest for this station are the *vacuum* and the *pressure* values. We have two screens to display the statistics of these parameters: *Forming Process Pressure Screen* (fig. 4.4) and *Forming Process Vacuum Screen* (fig. 4.5). Every second, FIX DMACS scans the addresses of the

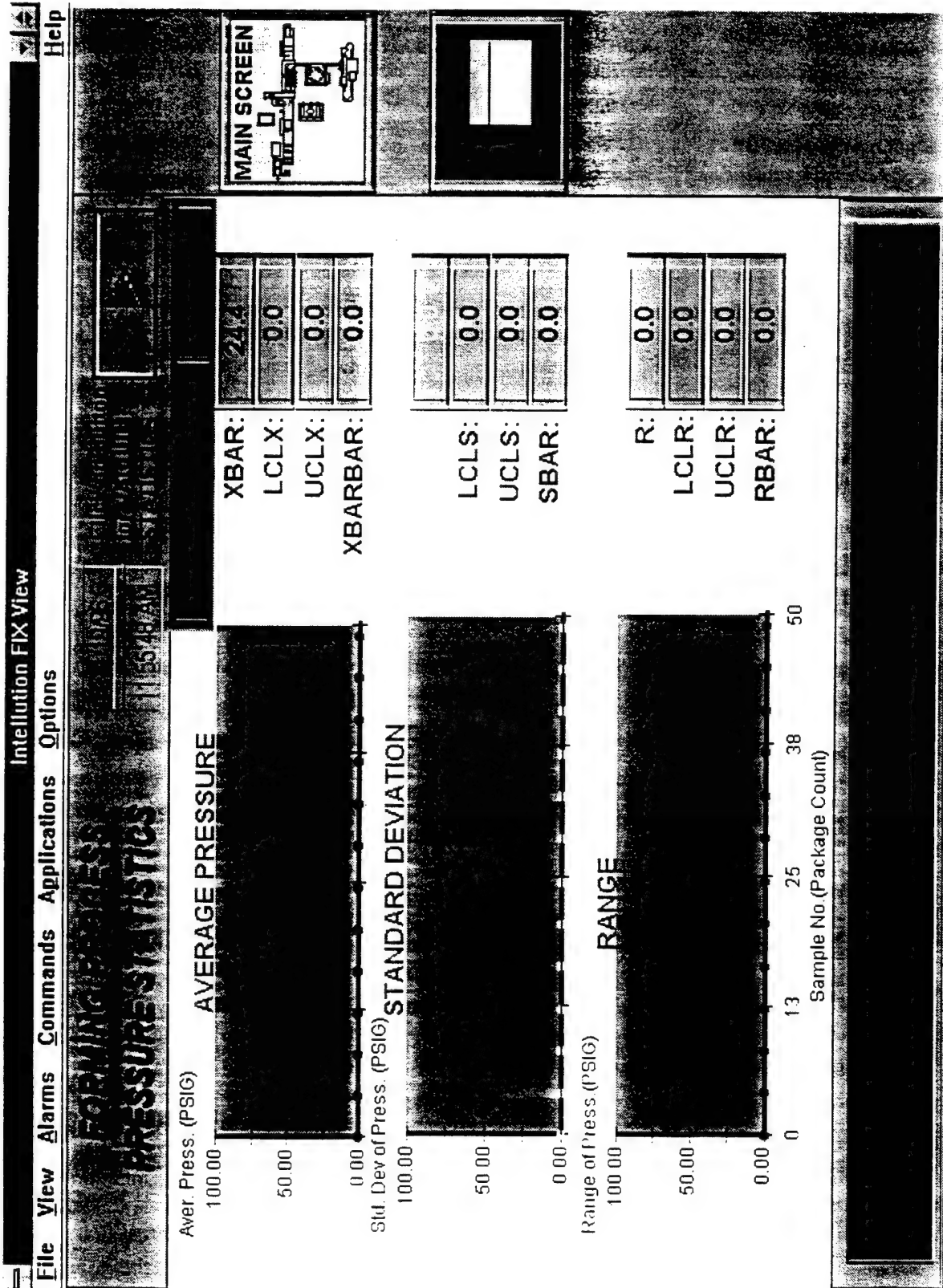


FIGURE 4.4: Forming Process Pressure Screen

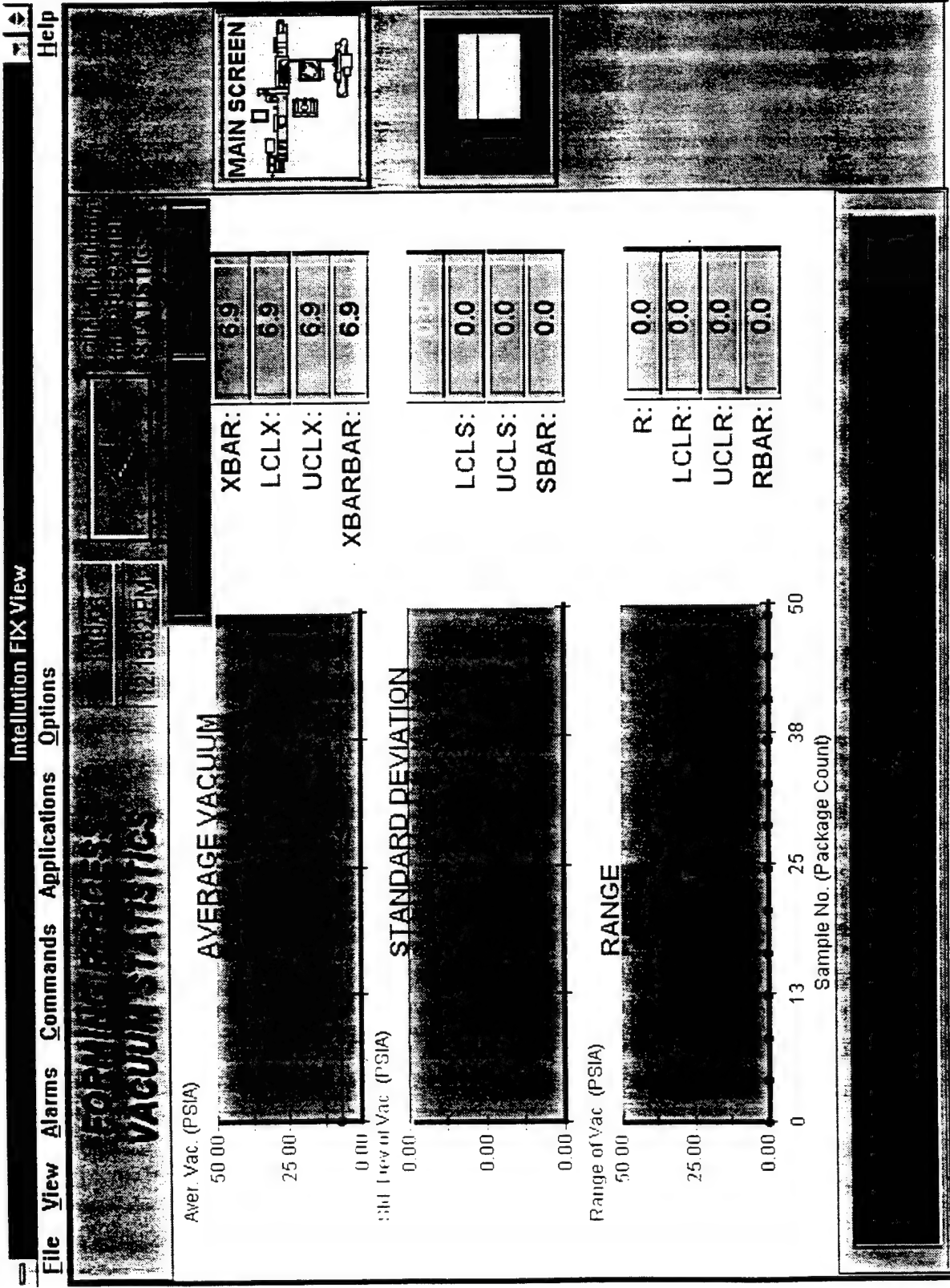


FIGURE 4.5: Forming Process Vacuum Screen

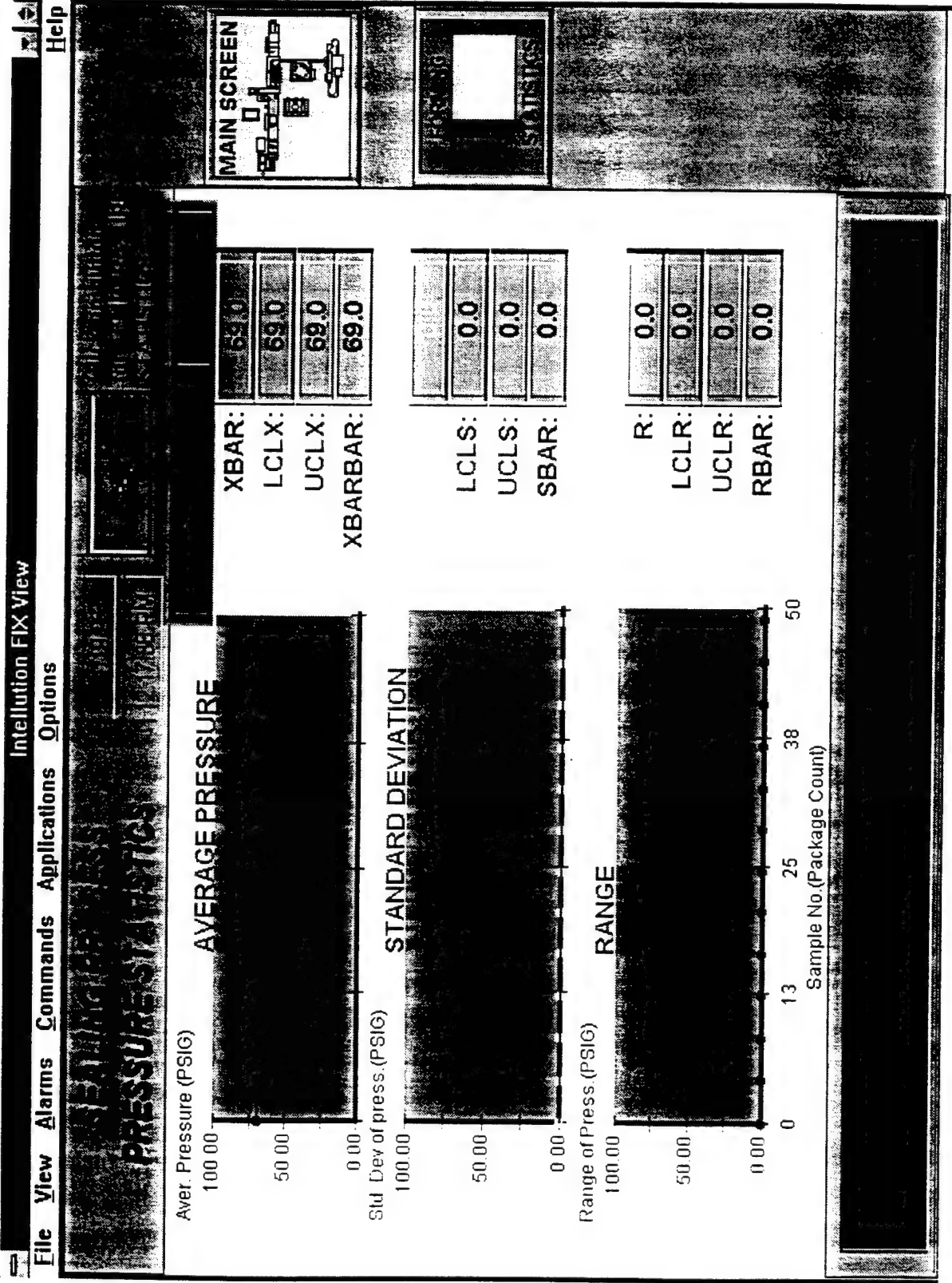


FIGURE 4.6: Sealing Process Pressure Screen

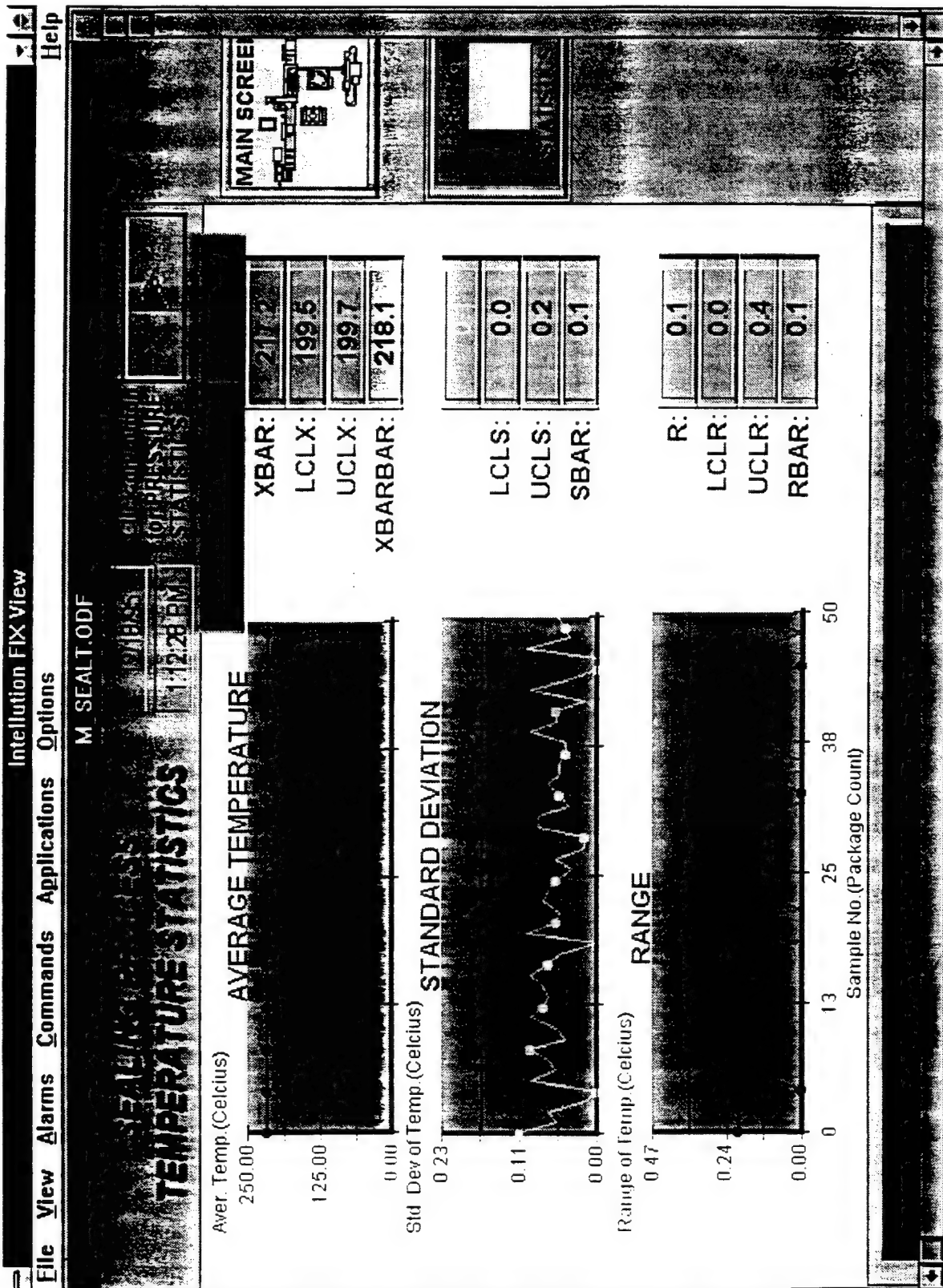


FIGURE 4.7: Sealing Process Temperature Screen

PLC2 which hold these two values. The two screens then display the following information:

1. Actual value of the forming pressure (vacuum): Scanned every second
2. X-Bar chart: Displays the average value of the forming pressure (vacuum)
3. S-Chart: Displays the standard deviation of the forming pressure (vacuum)
4. R-Chart: Displays the range of forming pressure (vacuum)

4.1.4. Sealing Process Pressure and Temperature Statistics

The sealing station is the post where the pouches are sealed. The two parameters of interest for this station are the sealing *temperature* and the *pressure* values. We have two screens to display the statistics for these parameters: *Sealing Process Pressure Screen* (fig. 4.6) and *Sealing Process Temperature Screen* (fig. 4.7). Type of information and the charts displayed are similar to the Forming process screens, as described in section 4.1.3.

4.1.5. Material Handling

In food manufacturing, it is essential to keep track of the materials and ingredients used so that in case of a rejected product or some other problems and complaints, all materials used in the production of the defective batch can be traced. We provide a *Material Tracking* screen for the MRE line. Refer to figure 4.8. We divide this screen into two dialog boxes: *Raw Material* dialog box and *Finished Material* dialog box. There are four main groups of raw material: Bottom web, top web, ham and beef stew. Ham and beef stew are the two current recipes that are produced on the MRE Line. The only ingredient for a ham recipe is ham. Beef stew, on the other hand, has three ingredients; vegetables, sauce and beef cubes. Current setup requires that the operator enters the LOT ID and START TIME of the material lot manually. The operator will be prompted on what is required at each step. For example, if he wants to report on the material "ham", he should click on the arrow on HAM line. First the lot ID and then the start time of that particular lot will be requested. The data entered will appear on screen to check. If any mistake is made, the same procedure can be repeated before sending the data to the plant data base. The operator will then be prompted to click on SAVE1 to send the data to the plant database. A message will appear when the data transfer is complete. The procedure is the same for the other raw materials as well. Only in case of the beef

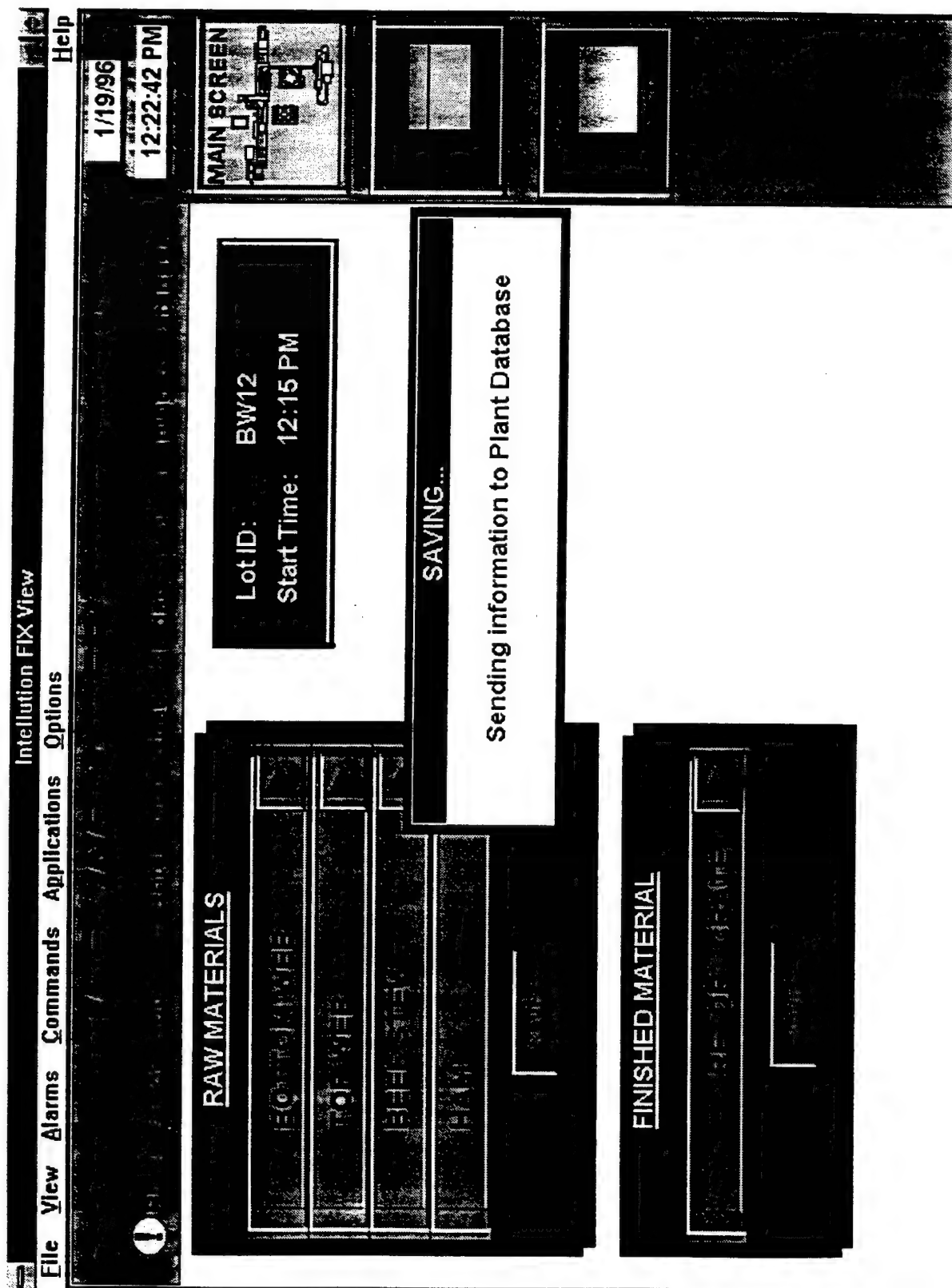


FIGURE 4.8: Material Handling Screen

stew, another menu will appear upon clicking the arrow associated with beef stew. This menu contains the ingredients, vegetable, sauce and beef. Hence the operator is enabled to enter the material data related to each of these ingredients, separately.

The *Finished Material* dialog box refers to the retort crates. The procedure to follow to enter the related data is the same as described above. Since the filling rate of retort crates is very fast, crate data has to be entered very frequently. The current time is sent to the plant database along with the entered data. Unless the operator enters a different start time for a particular crate (i.e. there might be a delay between the actual start of filling a crate and entering the information), the current time value is taken as the start time of filling of that crate.

After data entry is complete the operator can switch to one of the screens: Main, Sealing Process or Forming Process.

4.1.6. Off Line Data Screen

This screen is a sample DDE interface to the screen for the Ham recipe (see figure 4.9). It is possible to enter the weights of ham pouches either manually or through a DDE link with the PMCOMM software. If the data is to be entered manually, the operator should click on the button MANUAL_ENTRY. He will be prompted to enter data as many times as depicted by the “sample size” data field. Once the data entry is complete, the sample average is plotted on an XBAR chart and the standard deviation and range values are also updated accordingly.

If the data is to be entered through the DDE link, both PMCOMM and FIX DMACS should be running at the same time. The operator should place the pouch on the scale. PMCOMM grabs the weight data. The operator clicks on DDE_ENTRY button and the data is transferred to FIX DMACS, plotted according to the sample size and the average values are sent to plant data base.

Clicking on RETURN button will switch the screen back to the *MRE Line main* screen.

4.1.7. Line Performance and Defect Data Screen

This screen (see fig 4.10) consists of three dialog boxes:

1) Pouch Defect Data dialog box: Each pouch is checked for the following defects once they leave the MRE line; Wrinkles, abrasion, delamination, tears/cuts, leakers, inadequate seal width and

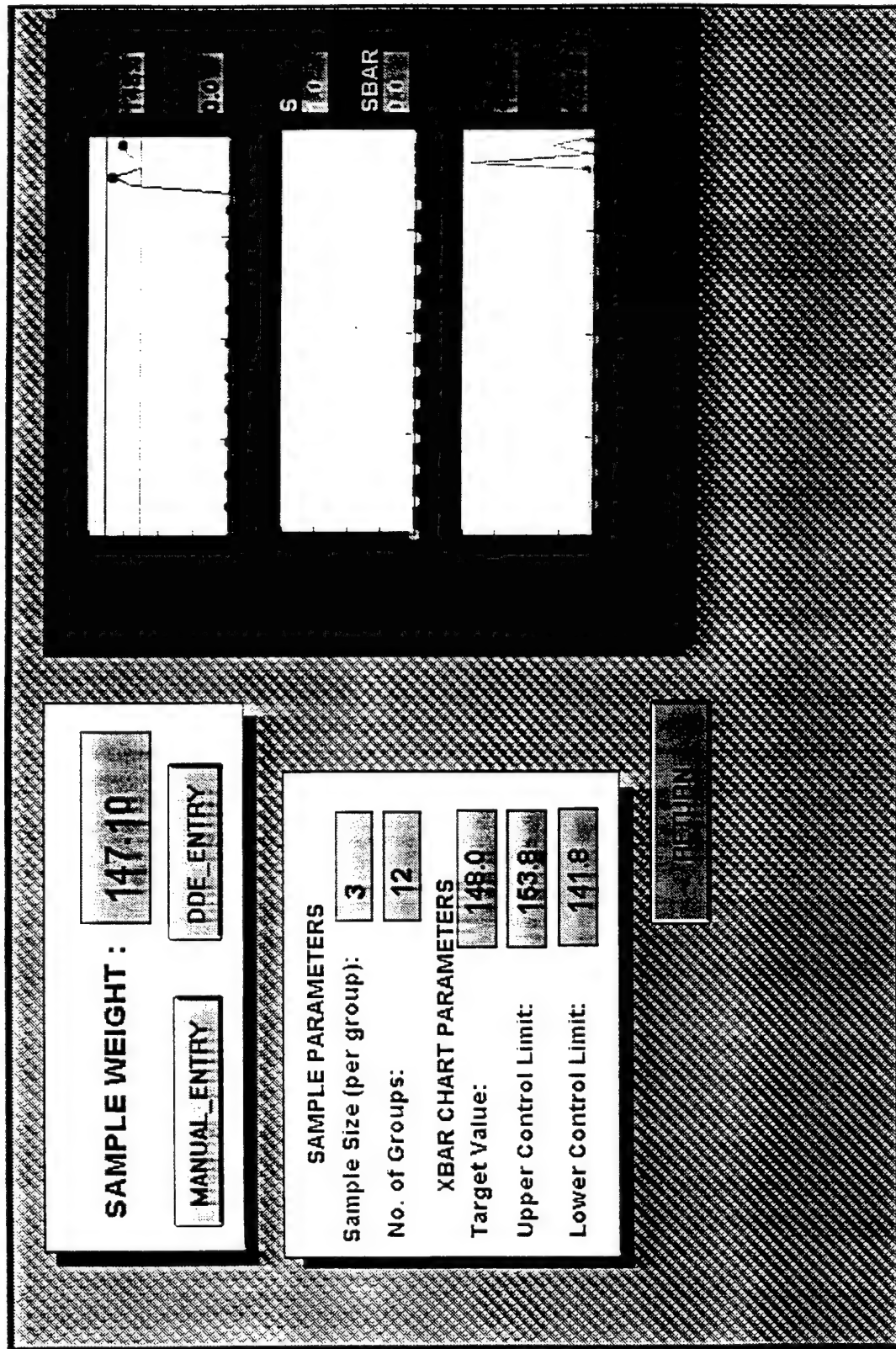


FIGURE 4.9: Off-line Data Screen

11/19/88

12:25:58 PM

Line Performance

PACKAGE COUNTS

Total Produced

:

0

pouches

Total Rejected

:

11

pouches

Total Scrapped

:

4

pouches

Total Sent to Retort:

:

0

pouches

% Yield

:

% ???

LINE EFFICIENCY

Line Speed

:

hr:min:sec

Busy Time

:

00:00:00

hr:min:sec

Idle Time

:

00:00:00

hr:min:sec

Cycle time

:

00:00

min:sec

POUCH DEFECT DATA

	Last Group	TOTAL
Wrinkles	1	2
Abrasion	1	3
Delamination	0	0
Tears/Cuts	1	3
Leakers	0	0
Inadequate Seal Width	2	2
Other	1	1
Scrapped	2	4

CANCEL

Press "CANCEL" just to Return to Main Screen

RETURN and RESET

Press "RETURN and RESET" to Return to Main Screen and Reset the Operator Timer

FIGURE 4.10: Line Performance and Defect Data Screen

others. Pouch Defect Data dialog box depicts a list of these defects with two data fields for each. The first data field refers to the defect data of the pouches produced in the last 15 minutes. The quality control personnel is required to enter the defect counts every 15 minutes. The timer on the MRE line *main screen* warns the quality control staff to enter defect data every 15 minutes, as described earlier. Once the timer signals, the staff should click on "Line Performance" button from the *main screen*. This will take him to the *Line Performance and Defect Data* screen. Now he can enter the data on the LAST GROUP fields of the defect data dialog box. Upon entering new data, FIX DMACS automatically updates the TOTAL defect values. Note that there is another category named SCRAPPED in this dialog box. It may be the case that some pouches are *scrapped* at the beginning of a shift or after some unexpected event during the production phase. These pouches belong to the "Scrapped" category and should be entered manually by the quality control staff or the operator. To enter data the operator should click on the LAST GROUP field of the related defect and enter the value. He can also go from one field to another using the "up" and "down" arrow keys.

2) Package Counts dialog box: Displays some summary information about the package counts. Table 4.1 below gives the type and source of the information displayed.

Type of Information	Source of Information
A. Total Produced	Calculated from PLC Index count
B. Total Rejected	Calculated in FIX (Sum of all defects)
C. Total Scrapped	Calculated in FIX (Sum of all entered "Scrapped")
D. Total Sent to Retort	Calculated in FIX [$D=A-(B+C)$]
E. % Yield	Calculated in FIX [$E=D/A$]

Table 4.1: Information for Package counts dialog box

3) Line Efficiency dialog box: Just like Package Counts dialog box, Line Efficiency dialog box displays some additional information about the performance of the MRE line. See table 4.2 below.

Type of Information	Source of Information
Line Speed	From PLC
Busy Time	FIX DMACS counter on start time
Idle Time	FIX DMACS counter on stop time
Cycle Time	Calculated in FIX (time between two indexing)

Table 4.2: Information for Line Efficiency dialog box

By clicking on RETURN and RESET button the timer is set to zero and the screen is switched to the *MRE Line Main* screen. Pressing the RETURN button will just switch the screen to the *MRE Line Main* screen and will not have any effect on the operator timer. Hence, if data is entered the operator should use RETURN AND RESET button. If no data is entered but the *Line performance and Defect Data* is visited only to check the values, then RETURN button should be used.

5. Alarming and Messaging

FIX DMACS defines *alarms* as a block condition indicating that a process value has crossed a predefined limit and requires a response. Database alarms provide the operator with important information about process values at his/her monitor. Alarms also require the operator to examine this information because they stay on the monitor until the operator acknowledges them. Finally alarms can automatically initiate a process sequence when an alarm occurs. This final feature of alarming hasn't been implemented for the MRE Pouch line yet.

For MRE line we have two types of alarming:

1) Custom designed alarms for the operator screens, like *main screen*: The system fault conditions and operator timers to collect data are examples to this group. To design these alarms, we used the object links and the dynamic property attributes that are provided in the *Draw* program. According to the real time data, these alarms will appear or disappear on operator's monitor. Below is a list of system fault conditions that are displayed as messages to the operator:

Station	Error Message
Forming	Forming cycle incomplete
	Forming tools failure (down)
	Forming tools failure (up)
	Lower web out
Sealing	Sealing cycle incomplete
	Sealing tools failure (down)
	Sealing tools failure (up)
	Upper web out
	High part detected
	Index watchdog failure
	Defective safety
	Analog or RTD card fault

Table 5.1: Fault conditions as displayed on operator screens

2) Database Alarms: An example to this type of alarm is the one generated by the SD block. We have set up this alarm for the process parameters of forming and sealing processes. There is a list of criteria for alarming within the SD block. Table 5.2 lists these criteria.

N point control limit alarm on XBAR
N point specification limit alarm on XBAR
N point warning limit alarm on XBAR
N point alarm on RBAR
N point alarm on SBAR
Trend of runs alarm
Length of runs alarm
N point critical runs alarm on XBAR

Table 5.2: Alarm criteria for SD blocks

There are four major SD blocks: SEAL_TSTAT (for sealing temperature), SEAL_PSTAT (for sealing pressure), FORM_PSTAT (for forming pressure), FORM_VSTAT (for forming vacuum). The current configuration of these blocks has the following two criteria for alarming: *N point Specification Limit Alarm on XBAR* (with N=3) and *Trend of Runs Alarm* (with N=5). For all of these blocks the number of groups, N, is set to 25. This means that among the 25 groups if any three of the group averages fall off the specification limits for any of these parameters then the related SD block will send an alarm to the specified areas (in this case both to the SCADA and the view nodes). In the later alarm type, there will be an alarm if five consecutive groups out of 25 show a specific trend like monotonically increasing or decreasing values. For more details on this type of alarming refer to section 6 of the TWP #103.

6. Conclusion:

In this report we described the FIX DMACS implementation of the MRE Pouch line. This document discusses how certain features of the FIX DMACS are utilized to collect, display and transfer data points from the MRE Pouch line. We recommend that the reader refers to TWP #103, the FIX DMACS manuals, MRE line database and the *.odf files for more comprehensive information.

References:

1. ABK I/O Driver Manual, Intellution.
2. FIX DMACS Alarming and Messaging Manual, Intellution.
3. FIX DMACS Command Language Manual, Intellution.
4. FIX DMACS Data Base Builder Manual, Intellution.
5. FIX DMACS Database Reference Manual, Intellution.
6. FIX DMACS Draw Manual, Intellution.
7. FIX DMACS Real Time ODBC SQL Application Manual, Intellution.
8. FIX DMACS Security Manual, Intellution.
9. FIX DMACS DDE Support Manual, Intellution.
10. FIX DMACS System Configuration Manual, Intellution.
11. FIX DMACS View Manual, Intellution.

CIMPRO '94

Conference on Computer Integrated Manufacturing in the Process Industries

April 25 - 26, 1994

Brunswick Hilton

East Brunswick, New Jersey, U.S.A

Supported by:

The National Science Foundation
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WELCOME TO CIMPRO '94

It is our pleasure to invite you to attend CIMPRO '94, an industry/academia forum for presenting current advances and applications of automation and computer integrated manufacturing in the batch and continuous process industries. The conference will be held on April 25-26, 1994 at the Brunswick Hilton in East Brunswick, New Jersey. Rutgers University is your host institution and the conference is sponsored by The National Science Foundation and The Defense Logistics Agency.

This conference will bring together researchers and practicing engineers from industry, government, and academia. The organizing committee has put together an outstanding program with over 80 speakers from 13 countries. Speakers are presenting their research and applications in the chemical, petrochemical, food, pharmaceutical, pulp and paper, and other process industries. The conference is an excellent opportunity to find out and evaluate what others in your industry and other process industries are doing in automation and computer integration.

The conference will also feature five tutorials given by leading authorities in areas related to the conference theme. These tutorials, which are listed in this brochure, will be held on Sunday, April 24 and Wednesday, April 27. In addition, the conference will have an exhibition of hardware and software from companies that serve the automation and computer integrated manufacturing needs of the process industries.

The Brunswick Hilton is located near the Rutgers University Campus in the greater New Brunswick area, approximately thirty three miles southwest of New York City and sixty miles north of Philadelphia. Frequent bus and railroad service connect New Brunswick with these cities, enabling the visitor to take advantage of their many attractions, such as theatres, museums, concerts and ballets, as well as other recreational and cultural resources.

Rutgers, The State University of New Jersey, is one of the major state university systems in the United States. The New Brunswick campus has over thirty-three thousand students studying for undergraduate and graduate degrees in fifteen degree granting divisions. The institution was chartered in 1766 as Queen's College, the eighth institution of higher learning to be founded in the American colonies. Dedicated to providing the highest quality education and research, Rutgers supports outstanding research centers to meet the needs of society and fulfill its role as The State University of New Jersey. The New Brunswick campus houses several high technology research centers, including the Center For Advanced Food Technology, Center for Computer Aids in Industrial productivity, Center for Fiber Optics Research, Center for Ceramics Research, Center for Discrete Mathematics and Theoretical Computer Science, and the Waksman Institute of Microbiology, among others. Visitors should take the opportunity to tour the campus and see some of these facilities.

Spouses and guests will find ample opportunity for diversion. Besides trips to New York and Philadelphia, daily excursions are available from New Brunswick to Atlantic City, with its gaming casinos, shows, restaurants and shopping. For naturalists, the 34,000 acre Edwin B. Forsythe National Wildlife Refuge is accessible by automobile and offers both auto and walking tours. It is the home of over 200 species of birds and late April is a good time for sighting shore birds and wading birds. For sports fans, the nearby Meadowlands sports complex hosts professional and college athletic events throughout the year. Top horses and drivers compete in harness racing at the Meadowlands race course in late April. Make your visit a vacation! Whatever your taste, you will find something stimulating to do. A special evening event of the conference is a banquet dinner and harbor tour of New York City aboard the World Yacht cruise. We look forward to meeting spouses and other guests during this social evening.

We hope to see you in New Brunswick.

CIMPRO '94 CONFERENCE CO-CHAIRS

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CIMPRO PROGRAM

Monday, April 25, 1994

Registration, Continental Breakfast				
8:00 - 9:00	Welcome Remarks			
9:00 - 10:00	Coffee Break			
10:00 - 10:15	MA 1 I. Karlinski Woodbridge Room	MA 2 D. Montgomery Edison Room	MA 3 V. Mahalec Piscataway Room	MA 4 N. Adam Board Room 2
10:15 - 11:45 Sessions	Lunch			
11:45 - 1:00	MB 1 H. Pham Woodbridge Room	MB 2 M. Phadke Edison Room	MB 3 F. DiCesare Piscataway Room	MB 4 M. Rao Board Room 2
1:00 - 2:45 Sessions	Coffee Break			
2:45 - 3:00	MC 1 J. Pekny Woodbridge Room	MC 2 L. Ungar Edison Room	MC 3 P. Yang Piscataway Room	MC 4 M. Shabrieri Board Room 2
3:00 - 4:30 Sessions	Departure to N.Y. City - Tour			
4:45 p.m.				

Tuesday, April 26, 1994

8:30 - 10:00 Sessions	TA 1 M. Pinedo Woodbridge Room	TA 2 A. Constantinos Edison Room	TA 3 S. Liebowitz Piscataway Room	TA 4 A. Gabriellian Board Room 2
10:00 - 10:15	Coffee Break			
10:15 - 12:15 Sessions	TB 1 J. Luxhoj Woodbridge Room	TB 2 M. Gursoy Edison Room	TB 3 L. Burke Piscataway Room	TB 4 M. Zhou Board Room 2
12:15 - 2:30	Lunch			
2:30 - 4:30 Sessions	TC 1 M. Tayyabkhan Woodbridge Room	TC 2 N. Frelman Edison Room	TC 3 C. Leem Piscataway Room	TC 4 F. Hendrickson Board Room 2

GENERAL INFORMATION

PRE-REGISTRATION Pre-registration for the conference is strongly recommended (NOTE: Pre-registration costs less than on-site registration.) Complete the enclosed pre-registration form and return with a check or money order (payable to IE Special Gift Fund) or a purchase order to CIMPRO '94, Department of Industrial Engineering, Rutgers University, P.O. Box 909, Piscataway, NJ 08855-0909. All attendees may pick up their registration packets at the registration desk. The deadline for pre-registration is March 1, 1994.

REGISTRATION The registration desk will be located on the main level at the Brunswick Hilton and will be open to accommodate pre-registered and on-site registrants during the following hours:

Sunday	April 24	3:00pm - 8:00pm
Monday	April 25	7:30am - 4:30pm
Tuesday	April 26	7:30am - 12:00noon

All attendees, including speakers and session chairs, must register and pay the registration fee. Your registration fee entitles you to a conference proceedings, attendance at all technical sessions and allows you to enter the exhibit hall - breakfasts and lunches for two days are included. Name badges are provided and must be worn to gain admittance to the exhibit hall and any CIMPRO session or function.

REGISTRATION RATES

	Before March 1	After March 1
Author/participant	U.S. \$175	U.S. \$225
Regular	U.S. \$225	U.S. \$275
Student	U.S. \$ 25	U.S. \$ 45

CANCELLATION AND REFUND POLICY Registration refunds will be made if written notice of cancellation is postmarked no later than March 15, 1994.

EXHIBITS Innovative software, hardware and reference materials

will be on display. Stop by for demonstrations of new and developing technology, browse through the latest book publications and enjoy a cup of coffee. Hours are as follows:

Monday	April 25	9:00am - 4:30pm
Tuesday	April 26	9:00am - 4:30pm

Meeting badges are required for admission. Companies interested in exhibiting may contact M. Jafari (908) 932-3627.

HOTEL - The Brunswick Hilton, Three Tower Center Boulevard, East Brunswick, is the site of the Conference. A limited number of rooms has been reserved at the Hilton - Conference rate of: U.S. \$79.00 per night (single or double occupancy). Reservation forms are included in this package, or you may call directly - Brunswick Hilton (908) 828-2000, or 1-800-HILTONS. Ask for the CIMPRO '94 Conference block of rooms. Attendees are advised to reserve their accommodations directly with the hotel as soon as possible.

Meeting sessions will be held in the following rooms: Woodbridge Room, Edison Room, Piscataway Room, Board Room 2. Please refer to this brochure to see where sessions and special events will be held.

SPECIAL SERVICES/ASSISTANCE Attendees who require special accommodations for hotel rooms, session rooms or special events may contact the hotel directly prior to the conference. During the conference, you may contact the information desk in the registration area.

TRANSPORTATION TO BRUNSWICK HILTON The four major airports in the Tri-State area are: Newark, JFK, Laguardia and Philadelphia. Transportation from Newark and JFK Airports is available from Princeton Airport (at a price of \$16 from Newark and \$22 from JFK). While at Newark or JFK Airports you can dial direct for transportation just by dialing "22" for the Princeton Airport. For more information please call (609) 587-6600 or 1-800-468-6696. For transportation from Laguardia you would need to take a taxi to Penn Station, take the train into New Brunswick, then take a taxi to the Brunswick Hilton in East Brunswick. For transportation from

Philadelphia you would need to take a taxi to the train station and take the train into New Brunswick, then take a taxi to the Brunswick Hilton in East Brunswick.

CLIMATE New Jersey has an average temperature climate of 65°F in April. Sweaters and warmer outer jackets are recommended. There is always the possibility of rain in the spring.

TOURS The Industrial Engineering Department of Rutgers University is sponsoring a Tour of Manhattan on a cruise yacht including dinner and sightseeing for the evening of April 25, 1994. The cost for the cruise is U.S. \$75 per person. For more information, please see brochures which are enclosed in your program package. Due to limited seating, registration for the tour must be completed before March 1, 1994. For everyone who enjoys a little excitement, transportation to Atlantic City and New York City are available. Further information will be available at the information desk at the Brunswick Hilton.

Monday 9:00 am - 10:00 am

Welcoming Remarks: *Rutgers University
National Science Foundation
Defense Logistics Agency*

Keynote Address: *Dr. James F. Mathis*
Chairman

*New Jersey Commission on
Science & Technology*

MA1: Monday 10:15 am - 11:45 am

Application of Scheduling in Process Industries

Chairman: *A. I. Karimi/Benger Laboratory,
E.I. du Pont de Nemours & Co., Fibers Department,
du Pont Blvd. Waynesboro, VA 22980*

**MA1.1 Optimal Production Planning and
Scheduling for Multiproduct Continuous Processing Plant,**
*D. Birewar/E.I. du Pont de Nemours & Co.,
Wilmington, DE 19803.*

**MA1.2 Impact of Random Breakdowns on the
Operation of Integrated Batch/Semicontinuous
Processes,** *S. Clark/Batch Process Technologies,
Inc., P.O. Box 2001, West Lafayette, IN 47906; G.
S. Joglekar.*

**MA1.3 Optimization Based Scheduling of a Batch
Processing Facility,** *D. J. Hoitomt/College of
Engineering, University of Connecticut, Box U-157,
Storrs, CT 06268; P. Luh.*

MA2: Monday 10:15 am - 11:45 am

**Statistical Process Monitoring and Control in the
Process Industries**

Chairman: *D. C. Montgomery/Department of
Industrial Engineering, Arizona State University, Tempe,
AZ 85287*

**MA2.1 Some Strategies for Integrating
Statistical Process Monitoring and Engineering Process
Control,** *D. C. Montgomery/Department of
Industrial Engineering, Arizona State University, Tempe,
AZ 85287.*

**MA2.2 Statistical Process Monitoring of
Multivariate Systems,** *C. M. Mastrangelo/
Department of Systems Engineering, Thornton Hall,
University of Virginia, Charlottesville, VA 22901;
G. Runger/Department of Decision Sciences
and Engineering Systems, School of Engineering,
Rensselaer Polytechnic Institute, Troy, NY 12180.*

**MA2.3 A Statistical Algorithm for Calibration of
an On-Line Viscosity Sensor,** *R. V. Baxley, Jr./Chemical
Group, Monsanto, Pensacola, FL 32502.*

MA3: Monday 10:15 am - 11:45 am

CIM in the Continuously Operating Process Industries

Chairman: V. Mahalec/VP and Technical Director, Aspen Technology, Inc., Ten Canal Park, Cambridge, MA 02141

MA3.1 Optimization of Plant Operation and Its Integration With Plant Design, A. B. Coon/
Aspen Technology, Inc., Ten Canal Park, Cambridge MA 02141; H. Britt.

MA3.2 A Knowledge-Based Scheduling System for the Distribution of Refined Products, L. W. Bezanson/
SETPOINT, Inc., 14701 St. Mary's Lane, Houston, TX 77079-2995; R. Fusillo.

MA3.3 A Fundamental Free Radical Kinetic Pyrolysis Model for On-Line Closed-Loop Plant-Wide Optimization of Olefins Plants, M. Meixell/
Dynamic Matrix Control Corporation, 9896 Bissonnet, Houston, TX 77036; G. E. Paules.

MA4: Monday 10:15 am - 11:45 am

CIM Information Systems In The Process Industries

Chairman: N. Adam/Graduate School of Management, Rutgers University, Newark, NJ 07102

MA4.1 Infusion of Electronic Commerce Into Computer Integrated Manufacturing, Y. Yesha/
University of Maryland, Baltimore County, Baltimore, MD 21228-5398.

MA4.2 Integrating Heterogeneous CIM Data Bases: The Case of Design to Cost, D. Dilts/
Department of Management Science, Faculty of Engineering, University of Waterloo, Waterloo, Ontario N2L 3G1 Canada.

MA4.3 A Prototype Natural Language Front-End to CRAMTD Database: A Computer Integrated Manufacturing System, N. Adam/Graduate School of Management, Rutgers University, Newark, NJ 07102;
A. Gangopadhyay/School of Business Management, Morgan State University, Cold Springs Land and Hiller Road, Baltimore, MD 21239.

MB1: Monday 1:00 pm - 2:45 pm

Production Planning and Scheduling

Chairman: H. Pham/Department of Industrial Engineering, Rutgers University, P.O. Box 909, Piscataway, NJ 08855

MB1.1 Scheduling Non-Identical Parallel Processors in Process Industries, T. Smith/Department of Industrial and Manufacturing Engineering, Oregon State University, Corvallis, OR 97331-2407; S. Randhawa.

MB1.2 Dispatching Material Handling Robots in a Continuous Chemical Process With Time-Window Constraints, L. Lei/Graduate School of Management, Rutgers University, Newark, NJ 07102.

MB1.3 A Dispatch Rule With Rolling Prediction Horizon for Chemical Flowsheets, L. Gimeno and M. Campos/School of Electrical Engineering, State University of Campinas, Campinas, Brazil; M. Rodrigues/School of Chemical Engineering, State University of Campinas, Campinas, Brazil; C. Passos/Automation Institute, Technical Center for Informatics, Campinas, Brazil.

MB1.4 Cyclic Production Planning Without Losing Flexibility, P. Simons/Eindhoven University of Technology, Graduate School of IE/MS, P.O. Box 513, Pav F12, NL-5600 MB Eindhoven, The Netherlands; J. Fransoo, and J. van Dijk.

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MB2: Monday 1:00 pm - 2:45 pm

Robust Design Method and Its Deployment

Chairman: M. S. Phadke/Phadke Associates, Inc., 15 Fairfield Drive, Tinton Falls, NJ 07724-3113

MB2.1 Developing Robust Chemical Batch Processes, G. Taguchi/2-12-15 Higashi-Nakano, Nakano-Ku, Tokyo 164, Japan.

MB2.2 Robust Design for Flexible Concurrent Engineering, D. P. Clausing/Massachusetts Institute of Technology, Room 35-329, 77 Massachusetts Avenue, Cambridge, MA 02139-4307.

MB2.3 Implementing Robust Design Methods at Ford, M. Billimoria/Ford Design Institute Fairlane Plaza South, Suite 700, Dearborn, MI 48126.

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MB3: Monday 1:00 pm - 2:45 pm

Modeling and Analysis of Production Systems

**Chairman: F. DiCesare/ECSE Department,
Rensselaer Polytechnic Institute, Troy, NY 12180-3590**

**MB3.1 Design, Verification and Performance
Evaluation of Production Control by Hierarchical
High-Level-Nets, R. Knorr/Fakulty for
Informatics and Automation, Technical University of
Ilmenau, Ilmenau, Germany; W. Fengler.**

**MB3.2 Modeling and Analysis of Production
Systems Using a Petri Net Based Approach, W. van
de Aalst/Department of Mathematics and Computing
Science, Eindhoven University of Technology, Eindhoven,
The Netherlands.**

**MB3.3 Modeling, Analysis and Simulation of a
Polymer Production Plant by Means of Arc-Timed Petri
Nets, U. Christmann/Department of Chemical
Engineering, Universitaet Dortmund, Dortmund, Germany;
H. Hanisch.**

**MB3.4 MIDAS, An Asynchronous, Distributed
Approach to Inventory Management: Modeling and
Simulation, J. Law/Division of Engineering,
Brown University, Providence, RI 02912; S. Ghosh.**

MB4: Monday 1:00 pm - 2:45 pm

Information Systems for Process Industry

**Chairman: M. Rao/Intelligent Engineering
Laboratory, Department of Chemical Engineering,
University of Alberta, Edmonton, T6G 2G6, Canada**

**MB4.1 Integrating Decision Support Systems With
Legacy Systems, H. Singh/E.I. du Pont de Nemours,
Experimental Station, P.O. Box 80101, Wilmington, DE 19880.**

**MB4.2 Integrated Quality Control and Process
Management Concepts for Chemical Processes, P.
Jokinen/Neste Engineering, Porvoo, Finland;
M. Sourander.**

**MB4.3 Implementing Organizational Structures in
Process Industry Supported by Tool-Based Reference
Models, T. Allweyer/Institut fur
Wirtschaftsinformatik, Universitat des Saarlandes,
Saarbrücken, Germany; M. Remme, and A-W. Scheer.**

**MB4.4 CIPS Architecture and Implementation,
M. Rao/Intelligent Engineering Laboratory,
Department of Chemical Engineering, University of
Alberta, Edmonton, T6G 2G6, Canada; Q. Wang, Q. Xia, H.
Farzadeh, Y. Ying, and S. Erlenback.**

MC1: Monday 3:00 pm - 4:30 pm

Scheduling in Chemical Process Industries

Chairman: *J. Pekny/School of Chemical Engineering, Purdue University, West Lafayette, IN 47907-1283*

MC1.1 The Value of Rigorous Scheduling Technology in Industrial Applications, *D. L. Miller Advanced Process Combinatorics, 713 Thorby Road Wilmington, DE 19803.*

MC1.2 A Heuristic Algorithm for a Constrained Cutting Stock Problem, *P. S. McCroskey/The Dow Chemical Co., Central Research and Development, Midland, MI 48674.*

MC1.3 A Comprehensive Approach to Chemical Process Planning and Scheduling, *G. V. Reklaitis/School of Chemical Engineering, Purdue University, West Lafayette, IN 47907-1283.*

MC2: Monday 3:00 pm - 4:30 pm

Fault Detection, Monitoring and Diagnosis of Industrial Processes

Chairman: *L. H. Ungar/Chemical Engineering Department, University of Pennsylvania, Philadelphia, PA 19104*

MC2.1 Slack-Descriptor Models for Monitoring Industrial Processes With Irregular Observations, *L. E. Holloway/Department of Electrical Engineering and Center for Robotics and Manufacturing Systems, University of Kentucky, Lexington, KY 40506-0108.*

MC2.2 Dynamic Fault Detection With The Automatic Process Evaluator, *L. H. Ungar/Chemical Engineering Department, University of Pennsylvania, Philadelphia, PA 19104; J. M. Vinson.*

MC2.3 IIFDS: An Integrated Intelligent Fault Diagnosis System for Process Industry, *J. Jiao/Management Department, J. Chal Department of Mechanical Engineering, Tianjian University, Tianjian, P. R. China; M. Rao Department of Chemical Engineering, University of Alberta, Edmonton, Alberta, Canada*

MC3: Monday 3:00 pm - 4:30 pm

Management Issues in The Implementation of CIM

Chairman: P. Yang/Executive Director,
Automation & Information Resources, Merck & Co., Inc., 1
Merck Drive, P.O. Box 100, Whitehouse Station, NJ
08889

MC3.1 Organizational Model for Implementing
Applications for the Manufacturing Enterprise, A.
Davidson/Director, Quality Systems Group, Merck &
Co., Inc., P.O. Box 4, WP62C6, West Point, PA 19486.

MC3.2 Response Time Management, K. Hedavi/
Intellection Inc., 1603 LBJ Freeway, #780, Dallas, TX 75234.

MC3.3 Computer Integrated Operation: A Johnson
and Johnson Perspective, G. Thompson/
Corporate Director of Advanced Technology,
Johnson & Johnson, New Brunswick, NJ 08903.

MC3.4 The Single Process View-Progress and
Barriers, P. Minor/CEO, INCODE Corporation,
250 Exchange Place, Herndon, VA 22070.

MC4: Monday 3:00 pm - 4:30 pm

Sensors and Process Automation

Chairman: M. R. Shahriri/Fiber Optic
Materials Research Program, Rutgers University,
P.O. Box 909, Piscataway, NJ 08855

MC4.1 Development and Use of Electrochemical
and Acoustic Chemical Sensors in Process Analytical
Chemistry, W. P. Carey/Department of Electrical
Engineering, FT-10, Center for Process Analytical
Chemistry, University of Washington, Seattle, WA 98195.

MC4.2 Physical Fiber Optic Sensors for
Process Control, E. Udd/Blue Road Research,
Inc., 2555 N.E. 205th Ave., Troutdale, Oregon 97060.

MC4.3 Fiber Optic Chemical Sensors,
M. Shahriri/Fiber Optic Materials Research Program, Rutgers
University, P.O. Box 909, Piscataway, NJ 08855.

TA1: Tuesday 8:30 am - 10:00 am

Planning and Scheduling Issues in the Process Industries

Chairman: M. Pinedo/Department of Industrial Engineering, Columbia University, New York, NY 10027

TA1.1 On Scheduling and Trim Problems in the Paper Industries, H. Shum/International Paper, 11 Skyline Drive, Hawthorne, NY 10532.

TA1.2 On Inventory and Scheduling Problems in the Process Industries, M. Pinedo/Department of Industrial Engineering, Columbia University, New York, NY 10027.

TA1.3 Building Quality Goals into the Business Plan, F. M. Tedesco/Juran Institute, Inc., Eleven River Road, P.O. Box 811, Wilton, CT 06897-0811.

TA2: Tuesday 8:30 am - 10:00 am

Artificial Intelligence and Neural Nets in Chemical Processing

Chairman: A. Constantinides/Department of Chemical Engineering, Rutgers University, P.O. Box 909, Piscataway, NJ 08855

TA2.1 Radial Basis Function Neural Networks for Process Control, L. H. Ungar/Chemical Engineering Department, University of Pennsylvania, Philadelphia, PA 19104; **T. Johnson III**.

TA2.2 Intelligent Systems for Integrated Process Operations Management, V. Venkatasubramanian/School of Chemical Engineering, Purdue University, West Lafayette, IN 47907-1283.

TA2.3 Knowledge Based Information Development System for Chemical Batch Processing, A. Constantinides/Department of Chemical Engineering, Rutgers University, P.O. Box 909, Piscataway, NJ 08855; **A. Hatfield**.

TA3: Tuesday 8:30 am - 10:00 am

Process Automation in Pharmaceutical Industry

Chairman: S. Liebowitz/Schering-Plough
*Research Institute, 2000 Galloping Hill Road,
Mailstop K-2-1 F-31A, Kenilworth, NJ 07033*

**TA3.1 Automation in Process Controls the
Pharmaceutical Unit Operational Processes, S.**
*Liebowitz/Schering-Plough Research Institute, 2000
Galloping Hill Road, Mailstop K-2-1 F-31A, Kenilworth, NJ
07033.*

**TA3.2 Real Solutions to Automation and
Information Systems In Pharmaceutical Applications,
D. M. DeJean/Executive Vice-President of SYS-TECH**
*Solutions, Inc., 4 Cedar Brook Drive North, Cranbury, NJ
08512.*

TA4: Tuesday 8:30 am - 10:00 am

**Software Specification and Development of Real Time
Control Systems**

Chairman: A. Gabrielian/Uniview Systems,
1192 Elena Privada, Mountain View, CA 94040

**TA4.1 Formal Specification and Verification of
Real Time Sequential Control Systems, A.**
*Gabrielian/Uniview Systems, 1192 Elena Privada,
Mountain View, CA 94040.*

**TA4.2 Distributed and Dynamic Shop Floor Control
in Intelligent Manufacturing Systems, D.**
*Veeramanil/Department of Industrial Engineering,
University of Wisconsin-Madison, 1513 University Avenue,
Madison, WI 53706.*

**TA4.3 Valid: An Environment Based on the
Rewriting Logic for the Formal Modeling of Manufacturing
Systems, A. Attoui/Laboratoire d'Informatique,
Universite' Blaise Pascal, Clermont-Ferrand II,
Cedex, France; M. Schneider.**

TB1: Tuesday 10:15 am - 12:15 pm

Scheduling and Production Management in Process Industry

Chairman: J. Luxhoj/Department of Industrial Engineering, Rutgers University, P.O. Box 909, Piscataway, NJ 08855

TB1.1 Graphical Receipt Management and Scheduling for Process Industries, P. Loos/Institut für Wirtschaftsinformatik, Universität des Saarlandes, Saarbrücken, Germany.

TB1.2 Dynamic Simulation for Improved Operation of Flexible Batch Plants, S. Engell/Fachbereich Chemietechnik, Universität Dortmund, Dortmund, Germany; **K. Wollhaf**.

TB1.3 Design of Manufacturing Planning and Control System in a Process Industry: A Case Study, J. Ashayeri/Tilburg University, P.O. Box 90153, 5000 Le Tilburg, The Netherlands.

TB1.4 Process Oriented Approach (POA) to Modeling Production Structures for Business Applications, M. Hofmann/Swiss Federal Institute of Technology, Ecole Polytechnique federale de Zurich, Zurich, Switzerland; **E. Scherer**.

TB2: Tuesday 10:15 am - 12:15 pm

Statistical Process Control

Chairman: M. B. Gursoy/Department of Industrial Engineering, Rutgers University, P.O. Box 909, Piscataway, NJ 08855

TB2.1 Uses of Principal Component Analysis for Disturbances Detection and Isolation, W. Ku/Chemical Process Modeling and Control Research Center, Lehigh University, Bethlehem, PA 18015; **R. Storer**, and **C. Georgakis**.

TB2.2 Development of Low-Order Nonlinear Models, L. Balasubramhanya/School of Chemical Engineering, Purdue University, W. Lafayette, IN 47907-1283; **F. Doyle III**.

TB2.3 A Multiple Criteria Optimization Approach to Robust Design, A. Song/Department of Electrical and Systems Engineering, University of Connecticut, Storrs, CT 06269; **K. Pattipati**, and **A. Mathur**.

TB2.4 Statistical Process Control in a PVC Manufacturing System: A Case Study, A. Ashayeri/Catholic University of Leuven, Belgium; and **J. Ashayeri**/Tilburg University, P.O. Box 90153, 5000 LE Tilburg, The Netherlands.

TB3: Tuesday 10:15 am - 12:15 pm

Applications of Neural Networks in Process Control

Chairman: L. I. Burke/Department of Industrial Engineering, Harold S. Mohler Laboratory 200, Lehigh University, Bethlehem, PA 18015

TB3.1 Neural Networks: An Overview With Examples, M. J. Piovoso/E.I. du Pont de Nemours & Co., du Pont Central Research Development, P.O. Box 80320, Wilmington, DE 19880-0320; **K. A. Kosanovich**.

TB3.2 Adaptive Neural Network Control Schemes for Unknown Nonlinear Dynamical Systems, S. R. T. Kumara/Department of Industrial Engineering, The Pennsylvania State University, University Park, PA 16802; **D. Sheen**.

TB3.3 An Improved Manufacturing Process Development Using Neural Network Based Control, H. H. Demirci and J. P. Coulter/Department of Mechanical Engineering and Mechanics, Lehigh University, Bethlehem, PA 18015; and **L. I. Burke**/Department of Industrial Engineering, Lehigh University, Bethlehem, PA 18015.

TB3.4 A Novel Associative Reinforcement Unit In the Field of Real-Valued Neural Computation, A. Vasilakos/Department of Computer Engineering, University of Patras, Patras, Greece; **N. Loukas**/Hellenic Air Force Academy, Dekeleia-Attiki, Greece.

TB4: Tuesday 10:15 am - 12:15 pm

Real Time Control Software Design and Analysis

Chairman: M. Zhou/Department of Electrical and Computer Engineering, New Jersey Institute of Technology, Newark, NJ 07102

TB4.1 A Control Software Design Method for CIM Systems, K. Venkatesh and R. Caudill/Department of Mechanical Engineering; **M. Zhou**/Department of Electrical and Computer Engineering, New Jersey Institute of Technology, Newark, NJ 07102; **E. Fernandez**/Department of Computer Science and Engineering, Florida Atlantic University, Boca Raton, FL 33431.

TB4.2 Estelle Specification of MAP/RT for a Field Bus, V. Garcia/Department of Mathematics, Universidad de Oviedo, Spain; and **E. Vazquez**/Department of Telematic Engineering, U.P. Madrid, Spain.

TB4.3 Efficiency of Triggering Places of Transitions for Distributed Local Control Based Petri Net, N. Nketsa/Laboratoire d'Automatique et d'Analyse des Systemes du CNRS, Toulouse, Cedex-France; **M. Courvoisier**.

TB4.4 Coloured Petri Nets as a Tool for the Specification and Verification of the CIM-Architectures, A. Borusan/Fachbereich Informatik, University of Hamburg, Hamburg, Germany.

TC1: Tuesday 2:30 pm - 4:30 pm

Scheduling Software in Industrial Use: Problems in its Development and the Implementation

Chairman: *M. T. Tayyabkhan/Tayyabkhan Consultants, Inc., 62 Erdman Avenue, Princeton, NJ 08540*

TC1.1 Process Planning and Scheduling as Part of an Enterprise Wide Business System, T. McKaskill/Ross Systems, Center Two, 1100 Johnson Ferry Road, Ste 750, Atlanta, Georgia 30342.

TC1.2 Challenge of Special Features for Process Industry Software, J. Scandar/Probe Software Sciences Ltd., 666 Sherbrooke W., Suite 800, Montreal, H3A 1E7, Canada.

TC1.3 Custom Software vs. Standard Product: Experiences of Vendors and Users, M. T. Tayyabkhan/Tayyabkhan Consultants, Inc., 62 Erdman Avenue, Princeton, NJ 08540.

TC2: Tuesday 2:30 pm - 4:30 pm

Issues in CIM

Chairman: *N. Fraiman/International Paper, 11 Skyline Drive, Hawthorne, NY 10532*

TC2.1 Critical Evaluation of Database Models in the Context of CIM Requirements, M. Islam/Systems Engineering Management, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia.

TC2.2 The Application of Management Systems on Engineering Data, P. Marcus/Defense Logistics Agency, Springfield, NJ, and Nova University, Fort Lauderdale, FL 33314.

TC2.3 An IDEF0 Reference Model for Manufacturing, D. Gong/Department of Industrial Engineering, Chung-Yuan University, Chung-Li, Taiwan, R.O.C.

TC2.4 Intelligent On-Line Monitoring and Control System for Pulp and Paper Processes, Q. Xia/Intelligent Engineering Laboratory, Department of Chemical Engineering, University of Alberta, Edmonton, Canada; M. Rao, H. Farzadeh, and Y. Ying.

TC3: Tuesday 2:30 pm - 4:30 pm

Process Control Using Neural Nets and Fuzzy Logic

Chairman: C. S. Leem/Department of Industrial Engineering, Rutgers University, P.O. Box 909, Piscataway, NJ 08855

TC3.1 Retort Optimization Through Neuro-Control Approach, C. Dagli and D. Rogers/Department of Engineering Management; D. Dawson/Department of Electrical Engineering, University of Missouri-Rolla, Rolla, MO 65401-0249.

TC3.2 Design and Implementation of Fuzzy Logic Embedded Programmable Logic Controllers for CIM Process Control, S. Nerurkar/Hi-Tech Solutions, Inc., North Cranbury, NJ 08512; and M. Zhou/Department of Electrical and Computer Engineering, New Jersey Institute of Technology, Newark, NJ 07102.

TC3.3 A Comparison of Neural Networks and Fuzzy Logic Systems for Nonlinear Model Identification, J. Liskal/Department of Chemical Engineering, Clemson University, Clemson, SC 29634-0909; S. Melsheimer.

TC3.4 Soft Sensor Design and Implementation for Pulp Quality Prediction, M. Rao/Intelligence Engineering Laboratory, Department of Chemical Engineering, University of Alberta, Edmonton, T6G 2G6, Canada; J. Corbin, and Q. Wang.

TC4: Tuesday 2:30 pm - 4:30 pm

Process Control in Food Manufacturing

Chairman: F. Hendrickson/Center for Advanced Food Technology, Rutgers University, New Brunswick, NJ 08903

TC4.1 Comparison of Back Propagation Network (BPN) Performance and Response Surface Methodology (RSM) for Modeling Food Processes, V. Gnanasekharan/Department of Food Science, Purdue University, W. Lafayette, IN 47907-1280; J. Floros.

TC4.2 Controlling Temperature and Predicting Impending Temperature Upsets Using SPC and PID in a Production Fermentor, C. Giltner/Universal Foods Corporation, Milwaukee, WI 53201; J. Pan.

TC4.3 Real Time Integration of the Order Processing, Production Scheduling and Control Functions in the Industry for Highly Perishable Food, C. Begue/Industrial Engineering Department, University of Wisconsin-Madison, Madison, WI 53706-1572.

TC4.4 Methodology for Characterizing and Optimizing Batch Retort Systems, H. B. Bruins/Center for Advanced Food Technology, Rutgers University, Piscataway, NJ 08855.

Tutorial 1

**Title: ROBUST DESIGN:
A WAY TO ENHANCE INDUSTRIAL COMPETITIVENESS**

Registration Fee: \$200 Without Textbook / \$240 Including Textbook

Time: Sunday, April 24, 1:00 pm - 5:00 pm

Inventing new products, though necessary, is not enough to be an industrial leader in today's global competition. It must be coupled with innovative ways of developing and manufacturing products that **reduce the product cost, improve quality, and simultaneously reduce development interval**. Robust Design is one such methodology that was pioneered by Dr. Genichi Taguchi. The widespread use of the methodology in Japan has been a major reason behind Japan's success in capturing large shares of many world markets.

The fundamental principle of Robust Design is to make the main function of the product or the process least sensitive to all noises - environmental variations, manufacturing variations, and component deterioration. The main tools used in the methodology are:

1. Quadratic quality loss function to measure the loss due variation of the function.
2. Signal to noise ratio (S/N ratio) for predicting field quality, and
3. Orthogonal arrays to plan experiments involving many variables. The experiments may be conducted in hardware or using a computer model.

This tutorial describes the basics of Robust Design and give some actual engineering examples from my experience. It also discusses some of the recent advancements in flexible engineering and potential research areas.

**Instructor: Madhav S. Phadke, President,
Phadke Associates, Inc., Tinton Falls, NJ**

Madhav S. Phadke received B.S. (1969) degree in Mechanical Engineering from the Indian Institute of Technology, Bombay, M.S. (1971) degree in Mechanical and Aerospace Sciences from the University of Rochester, and M.S. (1972) degree in Statistics and Ph.D. (1973) degree in Mechanical Engineering from the University of Wisconsin-Madison. He pioneered the application and development of the Taguchi Method/Robust Design method in USA and is a recipient of the Taguchi Award, 1985. He is the author of the first engineering text book in English on Taguchi Method, *Quality Engineering Using Robust Design*, published by Prentice Hall, 1989.

Dr. Phadke is the President of Phadke Associates, Inc., a company specializing in quality technology deployment. He offers consultation and training in Robust Design, economic production quality system (EPQS), on-line quality control, and other methods of quality and productivity improvement. His clients include AT&T, ITT, Kodak, Allied Signal, Bellcore, McKinsey, Weirton Steel, and Senco. He has consulted on R&D and manufacturing projects in many disciplines - VLSI manufacturing, circuit design, aerospace components design, electrophotography (xerography), steel making, software development and testing, network design and operation, and system optimization. Many of these projects have led to multimillion dollar savings. His consultation with Kodak over a period of 14 months led to Kodak winning a praise from Dr. Taguchi as having made the fastest start in deploying the Robust Design method among all companies around the world.

In 1989, 1990, and 1993 Dr. Phadke offered a highly successful course in Taguchi Method via satellite through NTU. Previously, Dr. Phadke was a Supervisor in AT&T Bell Laboratories, a Visiting Scientist at the IBM Thomas J. Watson Research Center, and a Research Associate at the Statistics Department and the Mathematics Research Center at the University of Wisconsin-Madison. He has published numerous papers in the fields of off-line quality control, Kalman filtering, time series analysis, system identification and air pollution modeling.

Tutorial 2

Title: AN INTRODUCTION TO FIBER OPTIC SENSORS

Time: Sunday, April 24, 9:00 am - 4:00 pm

Registration Fee: \$250

Fiber Optic sensor technology offers a series of advantages with respect to prior art electrical sensors that are changing the way many current products are built and will open up the opportunity for many new systems. The light weight and small size of fiber sensors are strongly complemented by their strong immunity to electromagnetic interference eliminating the need for heavy and costly shielding. The result has been widespread interest in applying this technology in chemical, environmental, food, biomedical as well as aerospace industries. The automotive industry is looking for the use of fiber sensors in automobile engines and intelligent highways. The chemical, food and environmental industries are looking for the implementation of fiber optic chemical sensors for on-line, real time and long term monitoring of a variety of chemicals from toxic compounds to food flavor because the fiber sensors are made of glass they are environmentally rugged and can tolerate temperatures, vibration and shock. Other materials such as sapphire for very high temperatures and plastics for very low cost have also been effectively used. The medical profession is beginning to see widespread use of fiber optic chemical sensors for monitor constituents of the blood and drug dosage. This trend is expected to expand as cost and patient safety are critical issues that fiber optic sensors are well suited to address. Manufacturing control systems are being augmented by fiber optic smart structures technology and their use is becoming increasingly important where hostile or dangerous environmental conditions are involved, precluding the effective use of conventional approaches.

This one day course will provide a basic introduction to the field of fiber optic sensors and the many areas where this technology is being applied. The first half of the course, taught by Mahmoud Shahriari, will provide an overview on fiber optic sensor technology with the emphasis on intensity based fiber optic chemical sensors as well as IR

(infrared) sensors, including recent progress in fiber optic chemical sensor technology and their application in chemical process and control. The second half of the course, taught by Eric Udd, will cover an overview on phase sensors as well as spectrally based sensors, followed by a review of interferometric fiber sensors and the application areas of fiber optic smart structures and manufacturing.

Instructors: Eric Udd, Blue Road Research, Inc., Troutdale, Oregon, and Mahmoud Shahriari, Fiber Optic Materials Research Program Rutgers University, Piscataway, NJ

Eric Udd, MSE

President of Blue Road Research, Inc. in Troutdale, Oregon. Prior to founding Blue Road Research in 1993 to develop fiber optic sensor technology, Mr. Udd was a McDonnell Douglas Fellow at McDonnell Douglas Aerospace. Mr. Udd has had over 16 years of experience in the fiber optic sensor field and has acted as principal investigator and/or program manager on over 20 DOD, commercial and internal research and development of sensors. He has approximately 25 patents on fiber optic technology issued or pending. He has edited the book, *Fiber Optic Sensors: An Introduction for Engineers and Scientists*, Wiley, 1991.

Mahmoud R. Shahriari, Ph.D.

Associate Research Professor, Rutgers University, Ceramic Science and Engineering, Fiber Optic Program. Dr. Shahriari received B.S. degree in Chemical Engineering in 1976 from Aryamehr University of Technology in Tehran, Iran, and M.S. in Chemical Engineering in 1979 from The Catholic University of America in Washington, D.C. and Ph.D. in Materials Science in 1982 from the same university. Dr. Shahriari has had over 10 years of experience in the fiber optic sensor and optical materials fields and has acted as principal investigator on over 15 government and private industry grants and contracts. He has more than 40 papers published on fiber optic sensors and IR glasses since 1988. He holds one patent and 2 pending.

Tutorial 3

**Title: STATISTICAL PROCESS MONITORING AND CONTROL
FOR THE CHEMICAL AND PROCESS INDUSTRIES**

Time: Sunday, April 24, 1:00 pm - 4:00 pm

Registration Fee: \$200

Statistical process control, or SPC, based on standard Shewhart control charts has been widely used in the discrete parts industry. In many situations, these methods do not lend themselves directly to application in the chemical and process industry environment. These industries often have on-line instrumentation and measurement capability, and processes with long time constants. This induces autocorrelation in the observed processes variables. Standard control charts usually do not work effectively in these applications. The process industries also often utilize engineering controllers that minimize short term variation by automatic adjustment of controllable variables.

This course shows why serial autocorrelation frequently occurs and how simple time series models can describe process autocorrelation. Control chart procedures, based on residuals from an appropriate model, are developed that simultaneously display statistical control information and process dynamics.

We also describe techniques that are more effective against small process disturbances than are Shewhart charts. These techniques include the CUSUM and EWMA control charts.

Implementing SPC in a process with feedback or engineering control is also discussed. We show how control charts, used as statistical process-monitoring techniques, can be coupled effectively with engineering controllers to reduce short-term process variability. The effectiveness of these combined systems is illustrated in a wide variety of typical applications.

Instructor: Douglas C. Montgomery, Professor,
Industrial and management Systems Engineering,
Arizona State University, Tempe, AZ

Dr. Douglas C. Montgomery is Professor of Industrial and Management Systems Engineering at Arizona State University.

Dr. Montgomery's professional interests include manufacturing systems engineering, quality and reliability engineering, design of experiments, time series analysis, the design of forecasting systems, production and operations analysis and inventory and distribution systems design. He has lectured extensively throughout the Americas, Europe and the Far East and was a Visiting Professor of Engineering at the Monterey Institute of Technology in Monterey, Mexico. Dr. Montgomery has conducted basic research in empirical stochastic modeling, process control, and design of experiments. His research has been sponsored by private industry, the Department of Defense, the Department of Transportation, the Department of Commerce and the Department of Health, Education and Welfare.

Dr. Montgomery is an author of nine books, including *Probability and Statistics in Engineering & Management Science*, 3rd edition (with W. W. Hines), *Operations Research in Production Planning, Scheduling and Inventory Control* (with L. A. Johnson), *Forecasting and Time Series Analysis*, 2nd edition (with L. A. Johnson and J. S. Gardiner), *Design and Analysis of Experiments*, 3rd edition, *Introduction to Linear Regression Analysis*, 2nd edition (with E. A. Peck), and *Introduction to Statistical Quality Control*, 2nd edition. Professor Montgomery has authored over 50 papers which have appeared in many journals.

Dr. Montgomery's industrial experience includes engineering assignments with Union Carbide Corporation and Eli Lilly and Company. He also has extensive consulting experience with many national and international organizations.

He is a member of the honorary societies Phi Kappa Phi, Sigma Xi and Alpha Pi Mu. Dr. Montgomery was named Puget Sound Outstanding Industrial Engineer of the Year in 1986 and Engineer of the Year in 1987 by the Puget Sound Engineering Council. He is a recipient of the Ellis R. Ott Award and the Shewell Award. He has also received several outstanding teaching awards.

Tutorial 4

Title: CASE: AN APPROACH TO DEVELOPING INTEGRATED INFORMATION SYSTEMS

Time: Wednesday, April 27, 9:00 am - 11:00 am

Registration Fee: \$120

Integrated information systems have long been a desired goal of any company. Its many benefits include improved availability, timeliness and quality of information, a necessary ingredient to competitiveness in the market. Computer-Aided Software Engineering (CASE) is a necessary foundation to achieving these goals. CASE consists of:

1. A methodology for modeling the business in terms of data and functions.
2. Tools for capturing the models.
3. Tools for implementing information systems using these models.

This tutorial will cover the basic principles of Computer Aided Software Engineering and how it can be used to develop integrated systems. It will introduce some of the modeling techniques for modeling data and business functions and how these models form the basis of information systems needed by the company. Using examples based on Oracle CASE tools, this tutorial will show the progression from business-focused models to implemented applications in a relational database environment. It will also discuss some of the challenges presented by information needs in a process manufacturing environment and how they may be tackled.

Instructor: Ulka Rodgers, President, Group R, Inc.

Ulka Rodgers specializes in CASE and database management systems. Her particular skill is applying the best aspects of Information Engineering methodologies, CASE tools and DBMS product knowledge in practical application development. She is the author of *Oracle: A Database Developer's Guide* (Prentice Hall in Yourdon

Press Series, 1991), covering life-cycle development methods, and *UNIX Database Management Systems* (Prentice Hall in Yourdon Press Series, 1990) covering four major products - Informix, Ingres, Oracle, and Accell. She has over 10 years experience and has presented papers at international conferences on these topics. She is a well known author of articles which cover many issues experienced by application designers and developers who use database management systems products.

Ms. Rodgers is the founder of Group R, Inc. which provides consulting services to various clients on CASE, DBMS and 4GL products. Ms. Rodgers has developed models in industries including telecommunications, financial services, retail, and pharmaceuticals among others.

Using Oracle CASE, she has developed several large enterprise model for clients with the express objective of implementing an integrated set of business systems in Oracle. The scope included Accounting, Human Resources, Marketing, Sales, Business management, Product Management, Regulatory Affairs, and Consulting Practices. The detailed analysis involved building a function model and an entity-relationship model which would form the basis of selecting packaged software. Ms. Rodgers also assisted in defining the strategy for a new system for the group insurance sector of a major financial services company. She participated in evaluation and selection of productivity improvement tools ranging from Texas Instruments Information Engineering Facility on an IBM platform to DBMS and 4GL products such as Sybase on a DEC platform.

Ms. Rodgers received her B.Tech. in Computer Science, with First Class Honors, from Brunel University, U.K. in 1982. She is a member of the Association of Computing Machinery (ACM), IEEE/CS, The British Computer Society (BCS), and is a Chartered Engineer of The Engineering Council of U.K.

Tutorial 5

Title: IMPLEMENTING ISO 9000 QUALITY SYSTEM STANDARDS: A PARTICIPATING WORKSHOP

Time: Wednesday, April 27, 9:00 am - 5:00 pm

Registration Fee: \$500

The ISO 9000 Quality System Standards contain models of efficient quality systems which can provide customers with confidence in the supplier's ability to consistently meet requirements. It is expected that these standards will be used by customers in second party contractual situations and by registrars conducting third party certifications. This implies a growing importance of the standards to American industry.

This tutorial has four purposes:

1. To provide an understanding of the effect of ISO 9000 Standards on business relationships.
2. To identify questions that need to be answered to help decide whether or not an organization needs to comply with the standards.
3. To provide an understanding of the 20 elements of ISO 9001, the most comprehensive contractual standard.
4. To describe the process of registering quality systems to the ISO 9000 standards.

The Tutorial Leader, Dr. Sanford Liebesman, will present the material from the standpoint of an auditor reviewing a quality management system. And the attendees will be asked to respond to questions concerning the processes in their enterprises that may satisfy the ISO 9000 standards.

Attendees will be given a full set of notes, reference material and a copy of the ISO 9001 (or its US equivalent) Standard.

Instructor: Sanford Liebesman, AT&T Bell Laboratories,
Holmdel, New Jersey

Dr. Sanford Liebesman has 33 years of experience with Bellcore and Bell Labs. He was a District Manager at Bellcore and a Distinguished Member of Technical Staff at Bell Labs. Sandy has been a Malcolm Baldrige Examiner and is a subject matter expert on the ISO 9000 Series Standards. He has led or participated in 14 ISO 9000 audits at AT&T. Sandy has taught courses on quality, operations research and statistics at Rutgers University since 1977. He has published papers on many quality and reliability subjects. He has served in leadership positions on national and international quality standards bodies and on the IEEE Communications Society Quality Assurance Management Committee. Sandy graduated with distinction from the U.S. Naval Academy in 1957. He has MSEE and Ph.D. (Operations Research) degrees from New York University.

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Address _____

City _____ State _____ Zip _____

Arrival Date _____ Time _____ Departure Date _____ Phone# _____

Special Room Requests (space available basis only) _____

One night's deposit enclosed or Visa, Master Card, American Express, Diners Club, Carte Blanche: _____

Credit Card # _____ Expiration Date _____

Group Name _____

Check in time: 4 pm Check out time: 12 noon

Guaranteed Payment Reservation - Your rooms will be held until 6:00 am the following day. Unless cancelled, you will be held responsible for all space held and all remaining days will be released. Reservations may be cancelled 24 hours prior to arrival date.

One night's deposit/or credit card required to guarantee reservation.
 Special requests have been noted and will be filled upon arrival if available.
 Rates do not include applicable taxes.
 Credit is to be established prior to or at registration.
 Sorry, no pets allowed.

For further information call the hotel direct at: (908) 828-2000, or 1-800-HILTONS
 Please note: Deadline for CIMPRO block of rooms at \$79 is March 1, 1994.

Please fill out application and send to: Brunswick Hilton
 Attn: Reservations Department
 Three Tower Center Boulevard
 East Brunswick, NJ 08816-9804

REGISTRATION FORM FOR CIMPRO '94 CONFERENCE

25 & 26 APRIL, 1994 AT BRUNSWICK HILTON

Name _____ Organization _____

Address _____

Tel. No. _____ Ext. No. _____ Fax No. _____

Registration: By March 1 After March 1

Author/Participant U.S. \$175 U.S. \$225

Regular Registration U.S. \$225 U.S. \$275

Student Registration U.S. \$25 U.S. \$45

Extra Luncheon Tickets U.S. \$ 25 per lunch

Tutorials:

1 Robust Design; A Way to Enhance Industrial Competitiveness U.S. \$200 w/o Text
 U.S. \$240 w/Text

2 An Introduction to Fiber Optic Sensors U.S. \$250

3 Statistical Process Monitoring and Control for the Chemical and Process Industries U.S. \$200

4 Case: An Approach to Developing Integrated Information Systems U.S. \$120

5 Implementing ISO 9000 Quality System Standards: A Participating Workshop U.S. \$500

Conference Banquet Cruise No. of Tickets x U.S. \$75 per person = _____

TOTAL AMOUNT DUE

_____ Payment by cheque or money order enclosed. (Please make payment to "TE Special Gift Fund".)
 _____ Please Invoice: Purchase Order Enclosed

Please mail completed registration: CIMPRO '94 Conference Secretary
 Tel (908) 932-3654 Department of Industrial Engineering
 Rutgers University
 P.O. Box 909
 Piscataway, New Jersey 08855-0909
 U.S.A